AIRCRAFT
MECHANICS HANDBOOK

THE MAPLE PRESS YORK PA

PREFACE

Thousands of mechanics of various kinds are going to be needed to inspect, adjust and repair the large air fleet which is now being prepared in this country and as this is a new industry it has been deemed advisable to compile such facts regarding aircraft as may help to make these available in the shortest time. Except for a considerable amount of actual personal observation in both factory and flying field, no originality is claimed for this handbook; instead, it represents what is believed to be the best practice known at this time and contains many suggestions which cannot fail to be of value to any aircraft mechanic.

It is in the hope of aiding work of this kind, in helping to make our aircraft more efficient, that the work has been undertaken.

NEW YORK,
March, 1918.

THE AUTHOR.

INTRODUCTION

The first requirement of an airplane mechanic is reliability—there must be no guesswork about anything that goes to make up an airplane—everything should be right before a machine goes into the air. No good pilot starts a flight until he has tested his motor up to speed and knows that it will give him the necessary power. But the details of the plane, the wire rope and its connections, the eyes, the splicing or other fastenings, the pulleys over which the ropes run, the condition of the rudder and wing hinges and connections, must be taken care of by the mechanics. The failure to know that everything is right may not only mean the life of the pilot but, in military matters, the loss of valuable information and the death of hundreds of troops.

There are usually two mechanics assigned to each machine, one for the engine and propellor, or power plant, the other for the plane and all its connections. The English call the first the fitter and the latter the rigger; we substitute machinist for fitter and retain rigger or plane man for the other.

The machinist or fitter should thoroughly understand internal combustion motor construction and repair, and of as many types of motor as possible. Each has its peculiarities and should be studied so as to best know how to handle it. This is particularly true of the rotary type such as the Gnome and Rhone. We have comparatively few of these in this country but their peculiarities should be known, as well as how to take them down for examination and repair and to reassemble them, for this is quite an intricate task on some of the motors of this type. The parts must go together in a certain sequence or they will not go at all, as in a Japanese puzzle.

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THE AIRCRAFT MECHANICS HANDBOOK

SECTION I

THE GENERAL CONSTRUCTION

Although the modern airplane framework is apparently a simple arrangement of wood and wire, it will be found to contain many lessons in mechanical structures and is well worth considerable study. The combination of wooden spars and struts, secured against movement by suitable fittings and held in their proper positions by steel cables, forms an interesting engineering structure and one which the airplane rigger or mechanic must be familiar with if he is to do good work. The general construction is shown in Fig. 1 with the principal parts named.

The struts, as in all built-up structures, serve to hold the framework apart and in the proper position. They are always in compression and must be held firmly but not so tight as to spring the struts out of line as they can resist very little after they are bent, but continue to bend and break under a comparatively light load. Wood is very strong in direct compression but its resistance to bending is not great, particularly in the wood generally used for struts, which is spruce.

This should be straight-grained and free from defects of all kinds as the work of the strut is very important. Some of the rules of inspection call for spruce which has at least six rings, marking the yearly growth, to the inch. A few insist on eight rings to the inch, but this is almost impossible to secure. The distance between the rings shows the growth of the tree during

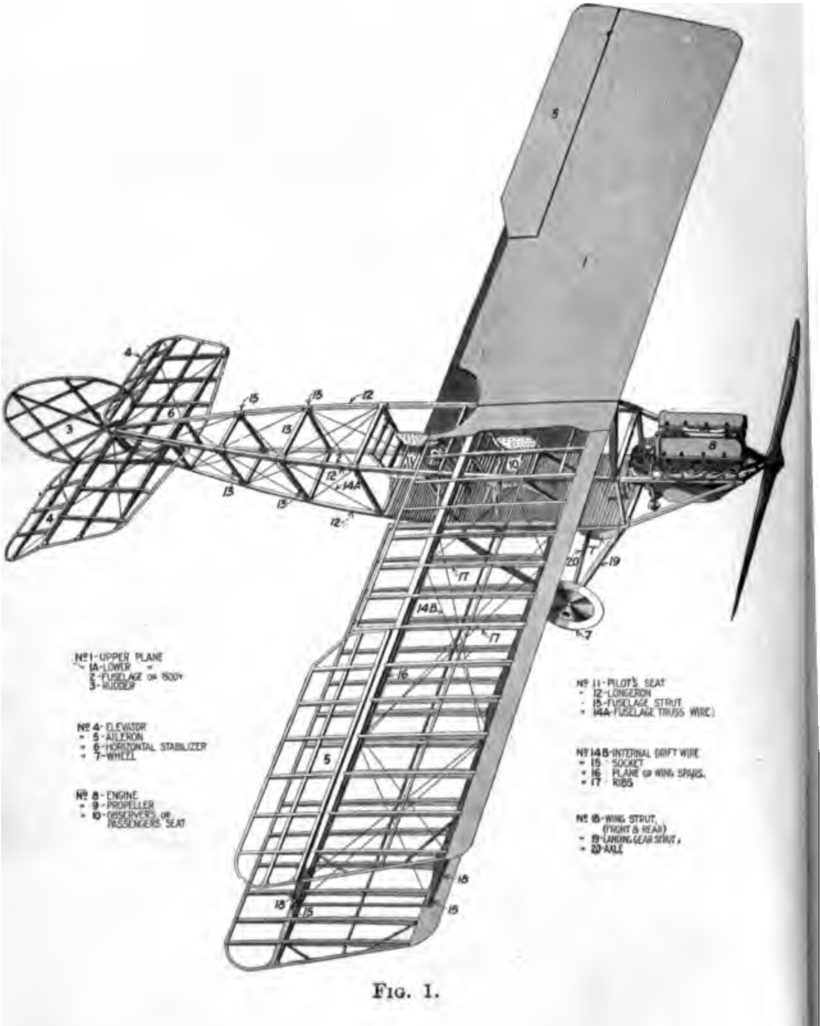

Nº 1-UPPER PLANE
" 1A-LOWER "
2-FUSELAGE OR BODY
Nº 4-ELEVATOR
" 5-AILERON
" 6-HORIZONTAL STABILIZER
" 7-WHEEL
Nº 8-ENGINE
" 9-PROPELLER
" 10-OBSERVERS OR PASSENGERS SEAT
Nº 11-PILOT'S SEAT
" 12-LONGERON
" 14A-FUSELAGE TRUSS WIRE
Nº 14B-INTERNAL DRIFT WIRE
" 15-SOCKET
" 16-PLANE OR WING SPARS
" 17-RIBS
" 19-LANDING GEAR STRUT,
" 20-AXLE

FIG. 1.

a single year and as a tree in good soil will grow much faster than a tree in poor soil, there will be fewer rings per inch even though the wood be equally sound and strong. Foresters say that a rapidly growing tree is more subject to disease and this is the basis for the demand for finely spaced rings. But excellent spars have been made from spruce having only two rings per inch, so that the exact number of rings per inch is not an infallible guide in choosing suitable wood for spars and struts.

The mechanic who would be a rigger has much to learn about the various parts of the framework and wings, for these must receive the most scrupulous care in every way. The center line of the body or fuselage must be straight and true, the planes at the rear which act as a stabilizer or balancer for the front of the machine must be in correct alignment, the wings or planes must be square with the fuselage and also at the correct angles when the whole machine is resting on a level floor. In other words, they must be in their proper position from every point of view, lengthwise, sidewise and frontwise, as a slight variation makes considerable difference in the handling of the machine and affects its stability and safety to a considerable degree. Some of these alignments can be checked up with the eye by a trained man but there are some which should be carefully measured if there is any reason to believe that the machine has been subject to undue stresses which may have twisted it somewhat out of shape.

The fuselage is a square-sectioned framework, in most cases, with the members separated by short struts, held in steel fittings, No. 15, and tied together by steel wires, No. 14*A*, running diagonally from strut to strut, No. 13, Fig. 1. The tension of these wires is very important not only as to amount but as to uniformity, and this is one of the fine points in the rigger's part of the work. With these wires too tight an undue stress is put on the strut and also on the wire itself, reducing the factor of safety in both cases. With unequal tension, unequal stresses are imposed on various parts of the frame and accidents are apt to occur from some part giving way. For even if the strut does not break but is bent out of shape this throws undue stresses on certain parts, shortens the distance between the surface it separates and otherwise disturbs the general layout of the machine. All these things interfere with the efficiency of the airplane and every drop in efficiency is serious in the case of a military machine, more so than in any other case. For efficiency is the one thing that enables the pilot to do his best work, and may easily mean the difference between victory and death.

The struts must be carefully watched to see that they are not damaged in any way, as if the outside fibers of the wood become splintered or bruised it makes a tendency to bend at this point and may lead to rupture just as a defect in the wood itself. The ends of the struts are also very important, particularly where they fit into the sockets and also the sockets themselves. These sockets should fit snugly and require pushing into place but should never be driven on with a heavy hammer owing to injury to the fibers of the wood. The strut should fit the socket well on its end so as to distribute the load evenly and avoid all tendency to split from bearing on a single point. One good plan is to paint the end of the strut and then note how it beds itself on the bottom of the socket after it is put into place.

In these days when it is not possible to get thoroughly seasoned woods, it is particularly necessary to watch against distortion due to uneven shrinking. This again tends to throw undue stresses on certain parts as when the strut is bent from uneven tension on the strut wires. By keeping the woodwork carefully varnished and never letting the bare wood be exposed to the atmosphere, this warping can be reduced to a minimum.

A good rule in all woodwork, which includes struts as well as the other parts, is to bore as few holes as possible for any purpose whatever. Every hole weakens the piece and the fact that the hole is filled makes no difference as to the strength of the piece as many seem to think. This makes it essential that the location of every hole be verified before it is bored so as to avoid unnecessary drilling and consequent weakening of the piece. Where holes are drilled, the size should be carefully determined, as the bolt or screw should be a good fit and not require driving in as this has a tendency to split the wood. A light tapping is not objectionable but the fit should not be tighter than this. On the other hand, the hole should not be large enough to let the bolt move in the wood. Either too tight or too loose may split the wood, the latter by working sideways and enlarging the hole to the danger point.

A careful study should be made of the methods used by the best builders in holding the various pieces of the framework together, both as to the fittings and the way in which they fit the wood and how the wires are connected to them. Sheet-metal stampings and drop forgings are being largely used with good results and care should be taken to note how they are designed to resist the various stresses and how they are used to enable quick assembly and rigid construction. Some fuselage fittings, for example, must be slipped over the whole length of the longeron while others can be put on at any point without disturbing any other fittings which may already be in place. Some require the ears which take the strut wires to be bent to the proper angle while others are so designed that the eye which receives the wire, swivels, and so adjusts itself to whatever angle the wire may assume under tension.

Where bolt heads and nuts fit against woodwork large washers must be used to prevent the metal, either nut or washer, being pulled into the wood and destroying the fibers. A large washer distributes the stresses over a large area and prevents this destructive pressure.

SECTION II

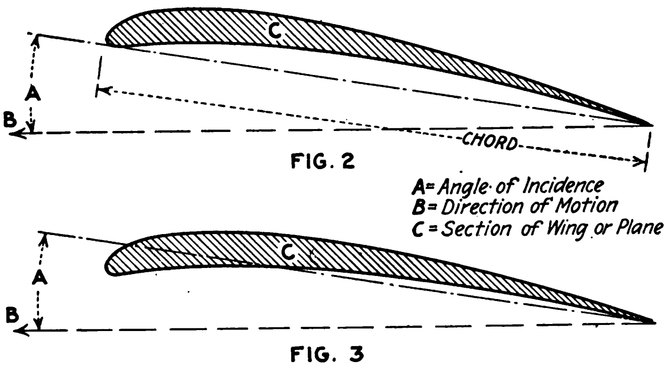
THEORY OF THE PLANES

In order for the rigger to be thoroughly efficient he must understand considerable theory of the construction of airplane wings and the essential features necessary for satisfactory flight. The importance of care and accuracy in this connection can hardly be overstated, for the pilot's life depends on the condition of the machine itself, for even should the engine fail with him high in the air he can usually land safely with the planes in good condition.

The rigger must know why a machine flies and what makes it stable. To insure this we shall take up a few of the points regarding modern airplanes.

A machine is supported in the air by driving it so that the air is forced under its inclined surfaces. These force the air down and the reaction of the air supports the planes. The inclination of these surfaces is called the angle of incidence and is measured when the plane is level or in its normal flying position, which is parallel with the shaft of the engine. In the side view of the surface shown the angle of incidence is that formed between the horizontal or line of motion and the chord, or straight line from one side of the wing to the other. This chord is the effective width of the wing. A more correct definition of the angle of incidence is the angle formed between the direction of motion and the neutral lift line, which starts at the trailing edge of the plane and runs along its main lifting surface, neglecting the downward curve of the front edge. The two methods are shown in Figs. 2 and 3. From a practical viewpoint the former is sufficient and enables the rigger to measure the angle more accurately than the other way.

The angle of incidence varies considerably in different machines: the Curtiss triplane scout has 3½ degrees; the twin-motored military tractor only 2 degrees; the training machine J N 4 B. 2 degrees; a hydro-airplane 4 degrees; and the flying boat 6½ degrees. On the other hand, the Standard Airplane Corporation use 2½ degrees on the training machine, 1¾ degrees on a training hydro, 5 degrees on a twin-motored military hydro and only 2 degrees on a military reconnaissance machine.



Figs. 2 and 3.—Measuring angle of incidence.

THE LIFT OF THE WINGS

The lift, secured by forcing the planes through the air, is due both to the direct reaction of the air against the lower planes and to the partial vacuum formed over the top of the wing, as at *A*, behind its leading edge as shown in Fig. 4. This is found to be over half the lifting force, in fact is usually considered as about three-fifths or 60 per cent., due to the upper surface of the plane. This makes it essential to keep the upper surface of the wing in good condition, especially as it is more apt to strip off the top than the bottom.

The resistance of the machine, or drift as it is often called, is made up of the resistance of the lifting surfaces, the passive resistance of the struts, propeller hub, wires, landing gear, etc., and the skin friction produced by the roughness of surface.

The efficiency of the machine itself, without regard to the engine which drives it, is due to the relation between the lift and

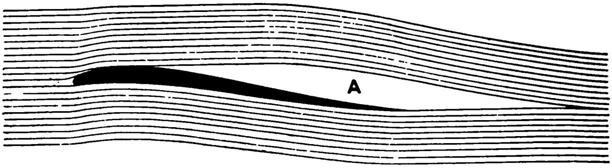


Fig. 4.—Action of air on wing.

the resistance or drift, this being known as the lift-drift ratio. The less the resistance the greater the efficiency of the machine so that every effort is made to decrease the resistance by stream-lining all parts which are exposed. This stream-lining is making the piece pointed not so much where it enters the air as where the air leaves it, as the passing air acts in the same way over the

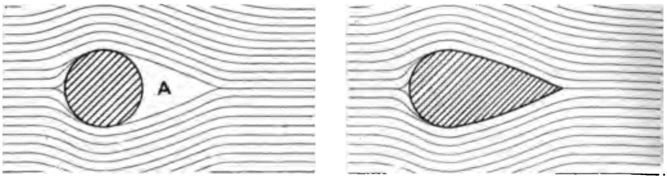


Fig. 5.—How air forms around struts.

top of the wing and creates a partial vacuum which holds back the piece and adds to the resistance. This is decreased by making the shape of the piece as shown in Fig. 5 which shows the effect of both round and stream-lined shapes. The space *A* shows the difference in vacuum created. It is for this reason that the landing wheels are covered and even the exposed wires are now being stream-lined on the highest-speed machines.

The camber of the wings is the curved surfaces at the top and bottom, the top being convex and the bottom concave. This camber varies greatly with the machine and the rigger can only assume that this, as with the angle of incidence, is rightly proportioned, and keep it in the condition in which he finds it. This is also true of the stagger of the planes, the rigger's work being to see that the proportions of the designer are maintained. The amount of stagger is sometimes given in inches, while other makers state it in degrees.

DIHEDRAL ANGLE

The dihedral angle, or the angle which the wings make with the horizontal, is to secure an inherent stability or self-righting

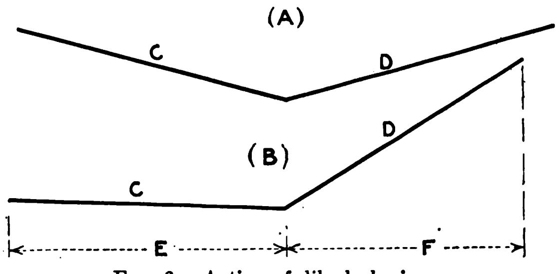


Fig. 6.—Action of dihedral wings.

quality to the machine. An exaggerated example of this is shown in Fig. 6 which shows the machine level at *A*, and tipping at *B*. As soon as the plane starts to tip the wing *C*, which goes down, immediately presents more surface to the air while the other wing *D* decreases its surface and the machine at once starts to right itself. The supporting area of each is represented by *E* and *F*.

The measuring of this dihedral angle can be done in two or more ways, the first or string method being the more satisfactory.

A cord or fine wire is stretched over the top of the wing as in Fig. 7 and held in several ways. A tripod may be used at one end and a weight at the other to keep it taut, or one end may be tied over the edge to a strut, or both ends may be secured in this way. Then, with the cord bearing on top of the wing at each end, measure the distance between the chord and the plane at definite points, taking equal points each side of the center panel of the machine. This should be done at both the front and back edges of the plane or, more properly, over the two main spars of the wing. This is done just as much to measure the angle on

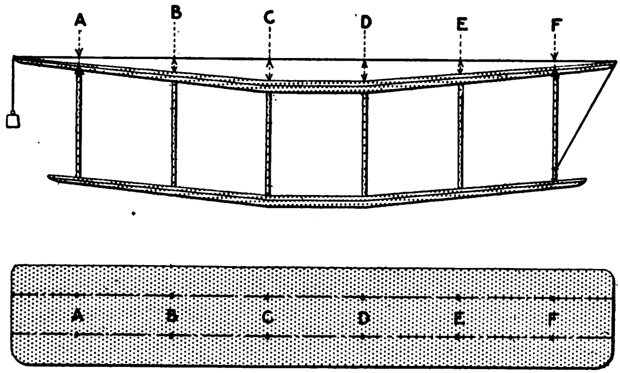


Fig. 7.—Measuring dihedral angle.

incidence as to check up the two sides of the machine and see that the angle is alike. By keeping notes of these measurements the rigger can easily detect any change which may occur.

Two strings should be used, one over each spar, and drawn very tight. The points measured should be just inside the four center section struts, in other words as far as possible from the center of the center section. Diagonal measurements are also taken, from similar points on each side of the machine. These measurements should be taken from fixed points, such as certain distances from the ends of the spars. Many take these measurements from the bottom socket of one strut to the top socket of another strut, but this is not good practice as this seldom gives accurate measurements. By measuring the distance between top and bottom planes it can readily be seen whether they are both set at the same angle.

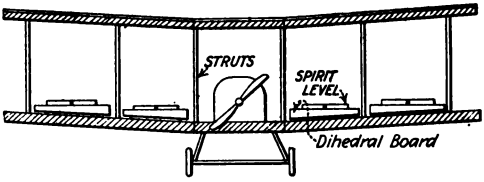


FIG. 8.—Use of dihedral angle board.

Another method and one which is easier to use although not usually as accurate is by the use of the dihedral board as shown in Fig. 8. This is simply a board cut with the proper angle for the dihedral on one side. These boards should be tested before

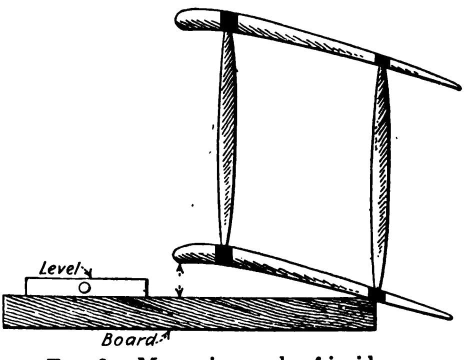


FIG. 9.—Measuring angle of incidence.

using and care must be taken that the spar is not warped or "set" at the points where they are used. For, as these must be used on the spars between the struts, slight inaccuracies often creep in from this source. The bays or sections between struts must be carefully measured diagonally as a check to the use of the boards. This same type of board is used to measure angle of incidence as shown in Fig. 9, but the level goes on the long, straight board. In all cases be sure the level is accurate.

MEASURING THE STAGGER

The amount of stagger is measured by dropping a plumb line from the leading edge of the upper plane and measuring back, as shown in Fig. 10. This can be measured either horizontally or along the

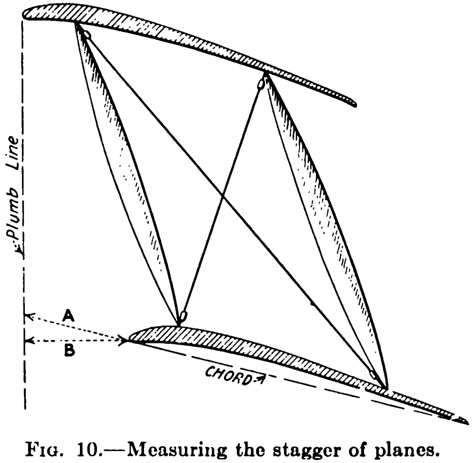


Fig. 10.—Measuring the stagger of planes.

line of the chord. Some makers measure one way and some another but the correct way should be shown on the diagram which should accompany every plane. This is the only way in which a rigger can check up his work as he goes along. The two measurements may be as much as a quarter of an inch difference, and while this may seem but a trifle, it may be enough to make the machine nose-heavy or tail-heavy as the case may be.

If any adjustments are found necessary, and they usually are, they should be very carefully made, taking great care not to spring any of the important parts such as the wing spars. It is also well to run over all adjustments after the last one is made to be sure that this has not thrown some of the others out of place.

After all other measurements have been taken and adjustments made the overall measurements will tell whether the machine as a whole is in good shape or not. These are taken in as Fig. 11. The points *A* and *B* are marked on the main spar, each the same distance from the butt or end next the fuselage.

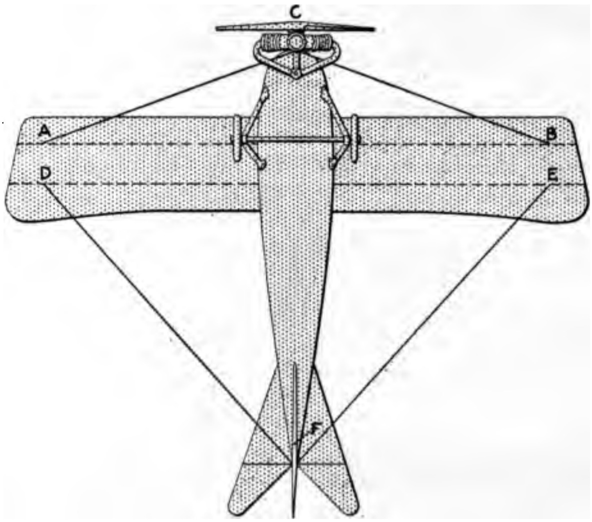


FIG. 11.—Measuring trueness of whole machine.

In a tractor machine the point *C* is the center of the propeller shaft, in a pusher, the center of the front end of the machine. From *A* to *C* and from *B* to *C* must of course be the same, these measurements being taken from both the top and bottom wing of the machine, making two measurements on each side of the machine.

In the same way mark two points D and E. on the rear spars of each wing and measure back to a point *F* in the center of the fuselage or rudder post. Here again two measurements are necessary on each side.

Should these measurements not check up as they should, it is possibly because some of the resistance or drift wires are not

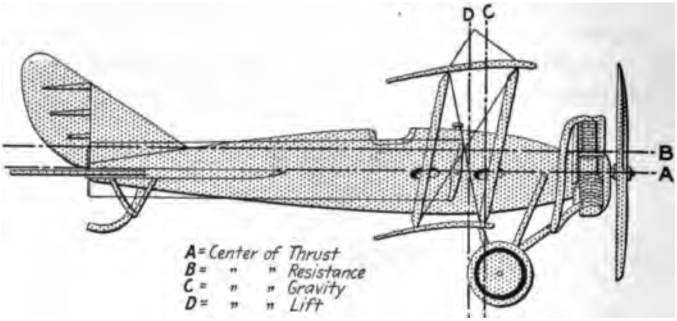


FIG. 12.—Location of thrust, resistance, gravity and lift.

tightened evenly, or the fuselage may possibly be out of true. This should, however, have been tested before the rest of the measurements were taken. The fault must be found and corrected before the machine is in condition to fly.

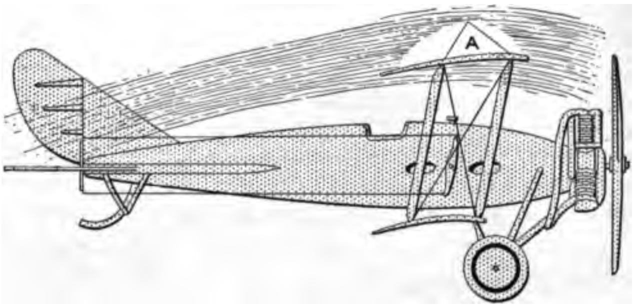


FIG. 13.—How air stream affects the tail planes.

A little study of Fig. 12 will enable the rigger to keep in mind some of the main points of the machine. It will be seen that the center of resistance or drift is above the center of thrust, or the center of the engine shaft, and parallel to it. The center of gravity is a little forward of the center of lift so that, with the power shut off, the machine will naturally assume its proper gliding angle, which should give the same speed as when flying.

As the air comes through the main planes it is deflected downward as shown in Fig. 13. This affects the angle of the tail plane, which may either be in line with this downward stream of air or at a lesser angle than the main wings. This stream of air affects the fore and aft stability of the machine.

THE STABILITY OF AIRPLANES.

The following notes on stability and stresses from the Manual of the Royal Flying Corps give many useful suggestions.

Stability

By the stability of the airplane is meant the tendency of the airplane to remain upon an even keel and to keep its course; that is to say; not to fly one wing down, tail down, or nose down, or to try and turn off its course.

Directional Stability.—By directional stability is meant the natural tendency of the airplane to remain upon its course. If this did not exist it would be continually trying to turn to the right or to the left, and the pilot would not be able to control it.

For the airplane to have directional stability it is necessary for it to have, in effect, more keel surface behind its turning axis than there is in front of it.

By keel surface is meant everything you can see when you look at the airplane from the side of it—the sides of the body, under carriage, wires, struts, etc. Directional stability is sometimes known as "weather cock" stability.

You know what would happen if, in the case of the weathercock there was too much keel surface in front of its turning axis, which is the point upon which it is pivoted. It would turn round the wrong way. That is just how it is with an airplane.

Directional stability will be badly effected if there is more drift (*i.e.*, resistance) on one side of the airplane than there is on the other side. This may be caused as follows:

1. The angle of incidence of the main planes or the tail plane may be

wrong. If the angle of incidence on one side of the machine is not what it should be, that will cause a difference in the drift between the two sides of the airplane, with the result that it will turn off its course.

2. If the alignment of the fuselage, the fin in front of the rudder, or with a machine having the front elevator and outriggers, these must be absolutely correct. For, if they are turned a little to the left or to the right, instead of being in line with the center of the machine and dead on in the direction of flight, they will act as an enormous rudder and cause the machine to turn off its course.

3. If the dihedral angle is wrong, that may have a bad effect. It may result in the propeller not thrusting from the center of the resistance, in which case it will pull the machine a little sideways, and out of its course.

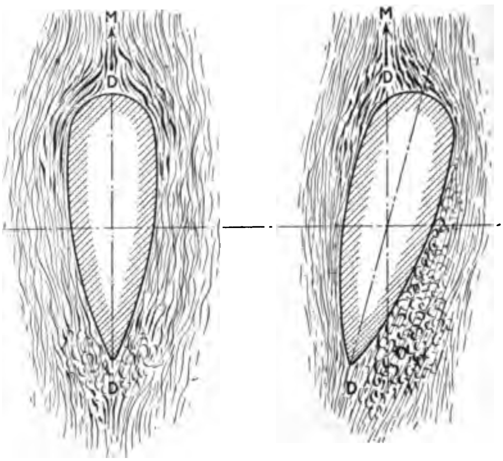


Fig. 14.—Air currents around struts.

4. If the struts and stream-line wires are not adjusted to be dead on in the line of flight, then they will produce additional drift on their side the airplane, with the result that it will turn off its course.

5. There is still one other reason why the airplane may be directionally bad, and that is *distorted surfaces.* The planes are "cambered," or curved to go through the air with the least possible resistance. If, perhaps owing to the leading edge, spars or trailing edge getting bent, the curvature is spoiled, that will change the amount of drift on one side of the airplane which will then have a tendency to turn off its course. See the struts in Fig. 14.

Lateral Stability.—By lateral stability is meant the sideways balance of the machine. The only possible thing that can make the machine fly one wing down is that there is more lift on one side than on the other. That may be due to the following reasons:

1. The angle of incidence may be wrong. If the angle of incidence is too great, then it will produce more lift than on the other side of the machine, and if the angle of incidence is too small, then it will produce less lift than on the other side, the result being that in either case the machine will try to fly one wing down.

2. *Distorted Surfaces.*—If the planes are distorted, then their camber or curvature is spoiled and the lift will not be the same on both sides of the airplane, and that, of course, will cause it to fly one wing down.

Longitudinal Stability.—Longitudinal stability means the fore and aft balance. If that is not perfectly right then the machine will try to fly nose down or tail down. This may be due to the following reasons:

1. *The Stagger May Be Wrong.*—The top plane may have drifted back a little and this will probably be due to some of the wires having elongated their loops or having pulled the fittings into the wood. If the top plane is not staggered forward to the correct degree then that means that the whole of its lift is moved backwards and it will then have a tendency to lift up the tail of the machine too much. In such a case the machine would be said to be "nose-heavy."

A ¼-inch error in the stagger will make a very considerable difference to the longitudinal stability.

2. Incorrect angle of incidence of the main planes will have a bad effect. If the angle is too great it will produce an excess of lift, which will lift up the nose of the machine and result in it trying to fly tail down. If the angle is too small there will be a decreased lift and the machine will try to fly nose down.

3. When the machine is longitudinally out of balance the usual thing is for the rigger to rush to the tail plane, thinking that its adjustment relative to the fuselage must be wrong. This is, indeed, sometimes the case, but it is the least likely reason. It is much more likely to be one of the first two reasons given, or the following:

The fuselage may have got warped upwards or downwards, thus giving the tail plane an incorrect angle of incidence. If the tail plane has too much angle of incidence it will make it lift too much and the machine will be "nose-heavy."

If the tail plane has too little angle of incidence then it will not lift enough, and the machine will be "tail-heavy."

4. If the above three points are all correct, then there is a possibility of the tail plane itself having assumed a wrong angle of incidence, in which

case it must be corrected. In such event, if the machine is nose-heavy, the tail plane should be given a smaller angle of incidence. If the machine is tail-heavy then the tail plane must be given a larger angle of incidence, *but* be careful not to give the tail plane too great an angle of incidence, because the longitudinal stability of the airplane entirely depends on the tail plane being set at a *much smaller angle of incidence* than the main plane, and if you cut the difference down too much the machine will become uncontrollable longitudinally. Sometimes the tail plane is set on the machine at the same angle of incidence as the main plane, but it actually engages the air at a lesser angle owing to the air being deflected downwards by the main planes.

Stresses and Strains

In order to rig a machine intelligently it is necessary to have a correct idea of the work every wire and every part of the airplane is doing.

The work the part is doing is known as *stress*. If, owing to undue stress, the material becomes distorted, then such distortion is known as *strain.*

Compression.—The simple stress of *compression* produces a crushing strain. As an example, the interplane and fuselage struts.

Tension.—The simple stress of *tension* results in the strain of elongation. As an example, all the wires.

Bending.—The compound stress of *bending* is composed of both tension and compression, one side is stretched, the other compressed.

Shear.—Shear stress is such that when the material breaks under it, one part slides over the other. As an example, the locking pins. Some of the bolts are in a state of shear stress also because, in some cases, there are lugs underneath the boltheads from which wires are taken. Owing to the tension of the wire the lug is exerting a sideways pull on the bolt and trying to break it in such a way as to make one part of it slide over the other.

Torsion.—This is a twisting stress composed of compression, tension, and shear stress. The propeller shaft and crankshaft of the engine is a good example.

Nature of Wood under Stress.—Wood, for its weight, takes the stress of compression the best of all. For instance, a walking stick of about half a pound in weight, will, *if* kept perfectly straight, probably stand up to a compression stress of a ton or more before crushing, whereas if the same stick is put under a bending load it will probably collapse to a stress of not more than about 50 pounds. That is a very great difference and since weight is of the greatest importance in an airplane, the wood, must, as far as possible, be kept in a state of *direct compression.* This it will do safely as long as the following conditions are carefully observed.

Conditions to be Observed.—1. All the spars and struts must be *perfectly straight.*

Fig. 15 shows a section through an interplane strut. If it is to be prevented from bending, the stress of compression must be equally disposed around the center of strength. If it is not straight, there will be more compression on one side of the center of strength than on the other side. That

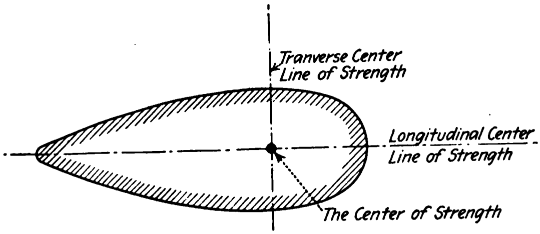


Fig. 15.—Section of strut.

is a step toward getting compression on one side and tension on the other side, in which case it will be forced to take a bending stress for which it is not designed.

Even if it does not break it will, in effect, become shorter, and thus throw out of adjustment all the wires attached to the top and bottom of it, with the result that the flight efficiency of the airplane will be spoiled,

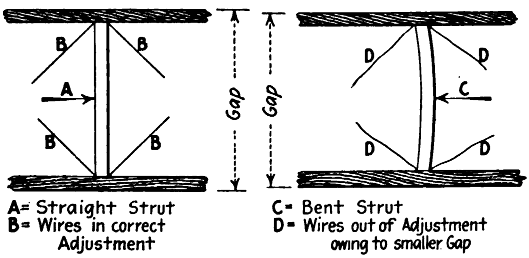


Fig. 16.—Effect of bent struts.

besides an undue and dangerous stress being thrown upon other wires, as in Fig. 16.

Where spars are concerned there is an exception known as *the arch.* For instance, in the case of the Maurice Farman, the spars of the center section plane, which have to take the weight of the nacelle, are arched upward. If this was not done it is possible that rough landings might result in the weight of the nacelle causing the spars to bend down a little. That would produce a dangerous bending stress, but as long as the wood is arched, or, at any rate, kept from bending downward it will remain in direct compression and no danger can result.

2. Struts and spars must be *symmetrical*. By that is meant that the cross-sectional dimensions must be correct, as otherwise there will be bulging places on the outside, with the result that the stress will not be evenly disposed around the center of strength, and a bending stress will be produced.

3. Struts, spars, etc., must be *undamaged*. Remember that, from what has been said about bending stresses, the outside fibers of the wood are doing by far the most work. If these get bruised or scored, then the strut or spar suffers in strength much more than one might think at first sight, and if it ever gets a tendency to bend it is likely to go at that point.

4. The wood must have a *good clear grain with no cross grain, knots or shakes*. Such blemishes mean that the wood is in some places weaker than in other places, and, if it has a tendency to bend, then it will go at those weak points.

5. The struts, spars, etc., must be *properly bedded* into their sockets or fittings. To begin with, they must be a good pushing or gentle tapping fit. They must never be driven with a heavy hammer. Then, again, they must bed well down, all over their cross-sectional area; otherwise the stress of compression will be taken on one part of the cross-sectional area with the result that it will not be evenly disposed around the center of strength, and that will produce a bending stress. The bottom of the strut or spar should be covered with some sort of paint, bedded into the socket or fitting, and then withdrawn to see if the paint has stuck all over the bottom of the fitting.

6. The atmosphere is sometimes much damper than at other times and this causes the wood to expand and contract appreciably. This would not matter but for the fact that it does not expand and contract uniformly, but becomes unsymmetrical, *i.e.*, *distorted*. This should be minimized by varnishing the wood well to keep the moisture out of it.

Function of Interplane Struts.—These struts have to keep the planes apart, but this is only part of their work. They must also keep the planes in their *correct attitude*. That is only so when the spars of the bottom plane are parallel with those of the top plane. The chord of the top plane must also be parwallel ith the chord of the bottom plane. If that is not so then one plane will not have the same angle of incidence as the other one.

It would only seem necessary to cut all struts the same length, but that is not the case. Sometimes, as illustrated in Fig. 17, the rear spar is not as thick as the main spar, and it is then necessary to make up for that lack of thickness by making the rear struts correspondingly longer. If that is not done, then the top and bottom chords will not be parallel, and the top and bottom planes will have different angles of incidence. Also, the sockets or fittings or even the spars upon which they are placed sometimes vary in thickness, and this must be offset by altering the length of the struts. The proper way to proceed in order to make sure that everything is right is to measure the distance between the top and bottom spars by the side of each strut and, if that distance, or "*gap*" as it is called, is not as specified in the rigging diagram, make it correct by changing the length of the strut.

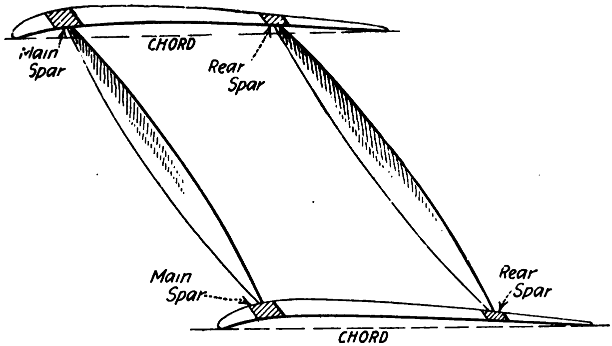


FIG. 17.—Length of struts.

When measuring the gap between the top and bottom spars *always be careful* to measure from *the center* of the spar, as it may be set at an angle, and the rear of the spar may be considerably lower than its front.

ADJUSTMENTS AND INSPECTION

Control Surfaces.—The greatest care must be exercised in properly rigging the aileron, rudder and elevator, for the pilot entirely depends upon them in managing the airplane.

The ailerons and elevator should be rigged so that *when the machine is in flight* they are in a fair line with the surface in front and to which they are hinged, as in Fig. 18.

If the surface to which they are hinged is *not a lifting surface, then rig* the controlling surface to be in a fair true line with the surface in front.

If the controlling surface is hinged to the back of a *lifting surface*, then it is necessary for it to be rigged a little below what it would be if it was in a fair true line with the surface in front. This is because in such a case it is set at an angle of incidence. This angle will, when the machine is flying, produce lift and cause it to lift a little above the point at which it has been rigged on the ground. It is able to lift owing to a certain amount of slack in the control wire holding it—and you can't adjust the control wire to have no slack, because that would cause it to bind against the pulleys and make the operation of it too hard for the pilot. It is, therefore, necessary to rig it a little below what it would be if it was rigged in a fair true line with the surface in front. Remember that this applies only when it is hinged to a lifting surface. The greater the angle of incidence of the lifting surface in front, the more the controlling surface will have to be rigged down. As a general rule you will be safe in rigging it down so that the trailing edge of the controlling surface is ½ to ¾ inch below where it would be if it was in a fair true line with the surface front—or ½ inch down for every 18 inches of chord of the controlling surface.

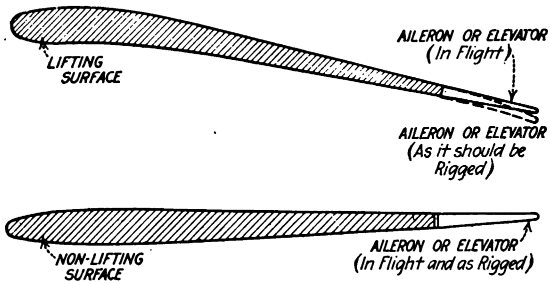


FIG. 18.—Rigging ailerons.

When adjusting the controlling surfaces the pilot's control levers must be in their neutral position. It is not sufficient to lash them in that position. They should be blocked into position with wood packing.

Remember that controlling surfaces must never be adjusted with a view to altering the stability of the machine. Nothing can be accomplished in that way. The only result will be that the control of the airplane will be spoiled.

Control Cables.—The adjustment of the control cables is quite an art, and upon it will depend to a large degree the quick and easy control of the airplane by the pilot. The method is as follows:

After having rigged the controlling surfaces remove the packing which has kept the control levers rigid. Then, sitting in the pilot's seat, move the control levers *smartly*.

Tension up the control cables so that when the levers are smartly moved there is no perceptible snatch or lag. Be careful not to tension up the cables more than necessary to take out the snatch. If you tension them too much the cables will bind round the pulleys and result in hard work for the pilot and also in throwing dangerous stresses upon the controlling surfaces, which are sometimes of rather flimsy construction. It will also cause the cables to fray round the pulleys quicker than would otherwise be the case.

Now, after having tensioned the cables sufficiently to take out the snatch or lag, place the levers in their neutral position and move them backward and forward not more than ⅛ inch either side of the neutral position. If the adjustment is correct you should be able to see the controlling surfaces move. If they do not move then the cables are too slack.

Flying Position.—Before rigging the machine it is necessary to place it in what is known as its "flying position."

In the case of an airplane fitted with a stationary engine this is best secured by packing up the machine so that the engine foundations are perfectly horizontal both *longitudinally* and *laterally*.

This is done by placing a straight edge and a spirit level on the engine foundations, and you must be very careful indeed to see that the bubble is exactly in the center of the level. The slightest error will be much magnified toward the wing tips and tail. Great care should be taken to block the machine up *rigidly*. In case it gets accidentally disturbed during the rigging of the machine, you should constantly verify the flying position by running the straight edge and the spirit level over the engine foundations. *Carefully test the straight edge for truth before using it*, for, being usually made of wood, it will not remain true long. Place it lightly in a vice, and in such a position that a spirit level on top shows the bubble exactly in the center. Now slowly move the level along the straight edge. The bubble should remain exactly in the center. If it does not, then the straight edge is not true, and must be corrected. *Never omit doing this.*

In the case of airplanes fitted with engines of the rotary type the "flying position" is some special position laid down in your rigging diagram, and *great care* should be taken to secure accuracy.

Propellers.—The last thing to go on to the machine is usually the propeller, by which time there is usually a rush to get the machine out. You must, however, be very careful to see that this is fitted on true and straight. This is easily verified by bringing the tip of one blade round to graze some fixed object such as a trestle. Mark the place where the tip of the blade touches it. Now bring the tip of the other blade round and it should be within ⅛ inch of the mark. If it is not so, then it is probably due to some of the propeller bolts being pulled up too tight. It may be due to the propeller itself not being true (see notes on propellers).

Fuselage.—The methods of truing fuselages are laid down in the rigging diagrams. After having adjusted the fuselage according to the specified directions, then arrange it on trestles in such a way as to make about three-quarters of the fuselage toward the tail stick out unsupported. In this way you will get as near as possible to flying conditions and, when it is in this position, you should run over the adjustments again. If this is not done the fuselage may be out of truth but perhaps appear all right when supported by trestles at both ends as, in such cases, its weight may keep it true as long as it is resting upon the trestles.

Tail Plane.—The exact angle of incidence of the tail plane is given in the rigging diagram. Be careful to see, however, that the spars are horizontal. If they are tapered spars then see that their center lines are horizontal. After the tail plane has been rigged, support the machine so that the tail is unsupported as explained above. Then verify the adjustment and make sure that the tail-plane spars are horizontal when the machine is in flying position.

Rudder, Ailerons, Elevator.—These controlling surfaces must not be distorted in any way. If they are held true by bracing wires then such wires must be carefully adjusted. If they are distorted and there are no bracing wires with which to true them up, then the matter should be reported as it may be necessary to replace some of the internal framework.

Undercarriage.—The undercarriage must be carefully aligned as laid down in the rigging diagram.

1. Be very careful to see that the undercarriage struts bed well down into their sockets. If this is not done then after having a few rough landings, they will bed down farther and throw the undercarriage out of alignment, with the result that the machine will not taxi straight.

2. When rigging the undercarriage, the airplane must be packed up in its flying position and sufficiently high so that the wheels are off the ground. When in this position the axle must be horizontal.

3. Be very careful to see that the shock absorbers are of equal tension, and that the same length of elastic and the same number of turns are used in the case of each absorber.

Handling of Airplanes.—An extraordinary amount of damage is done by the mishandling of airplanes and in packing them up from the ground in the wrong way. The golden rule to observe is:

PRODUCE NO BENDING STRESSES

1. Remember that nearly all the wood of the airplane is designed to take stress of direct *compression* and it cannot be safely bent. In packing an

airplane up from the ground the packing must be used in such a way as to come underneath the interplane struts and the fuselage struts. Soft packing should always be placed on the points upon which the airplane rests.

2. When pulling the machine along the ground always, if possible, pull from the undercarriage. If necessary to pull from elsewhere then do so by grasping the interplane struts as low down as possible.

3. As regards handling parts of airplanes. Never lay anything covered with fabric on a concrete floor, as any slight movement will cause the fabric to scrape over the concrete with resultant damage.

4. Struts, spars, etc., should never be left about the floor, as in such a position they are likely to become damaged, and I have already explained to you how necessary it is to protect the outside fibers of the wood. Remember also that wood easily becomes distorted. This particularly applies to the interplane struts. The best method is to stand them up in as near a vertical position as possible.

Keeping the Airplane in Good Condition

Cleanliness.—The fabric must be kept clean and free from oil, as that will rot it.

To take out dirt or oily patches try acetone. If that will not do the job try petrol, but use it sparingly or otherwise it will take off an unnecessary amount of dope. If that will not remove it, then hot water and soap will do so, but, in that case, be sure to use soap having no alkali in it as otherwise it will badly aflect the fabric. Use the water sparingly, as otherwise it may get inside the planes and rust the internal bracing wires, or cause some of the wooden framework to swell.

The wheels of the undercarriage have a way of throwing up a great deal of mud on the lower plane. This should be taken off at once. Do not allow it to dry and do not try to scrape if off when dry. If dry then it must be moistened first as otherwise the fabric will be spoiled.

Controlling Wires.—After every flight pass your hand over the control wires and carefully examine them near pulleys.

If only one strand is broken the wire must be changed. Don't forget the aileron balance wire on the top plane.

Once a day try the tension of the control wires by smartly moving the control levers about as explained elsewhere.

Wires.—See that all wires are kept well greased or oiled, and that they are all in the same tension. When examining your wires be sure to have the machine on level ground as otherwise it may get twisted, throwing some wires into undue tension and slackening others. The best way, if you have time, is to pack the machine up into its "flying position."

If you see a slack wire do not jump to the conclusion that it must be tensioned. Perhaps its opposition wire is too tight, in which case slacken it and possibly you will find that will tighten the slack wire.

Carefully examine all wires and their connections near the propeller, and be sure that they are snaked round with safety wire, so that the latter may keep them out of the way of the propeller if they come adrift.

Distortion.—Carefully examine all surfaces, including the controlling surfaces, to see whether any distortion has occurred. If distortion can be corrected by the adjustment of wire well and good, but if not then report the matter.

Adjustment.—Verify the angle of incidence, the dihedral angle, the stagger, and the overall measurements as often as possible.

Undercarriage.—Constantly examine the alignment and fittings of the undercarriage, and the condition of tires, shock absorbers and the tail skid.

Control Surfaces.—As often as possible verify the rigging position of the ailerons and elevator.

Locking Arrangements.—Constantly inspect the locking arrangements of all turnbuckles, bolts, etc.

Outside Position.—The airplane, when outside its shed, must always stand *facing the wind.* If this is not so, then the wind may catch the controlling surfaces and move them sharply enough to damage them. If the airplane must be moved during windy weather then the control levers should be lashed fast.

Inspecting.—Learn to become an expert inspector. Whenever you have the opportunity practise sighting one strut against another to see that they are parallel. Standing in front of the machine, which should be on level ground, sight the center section plane against the tail plane and see that the latter is in line. Sight the leading edge against the main spars, the rear spars and the trailing edges, taking into consideration the "wash-in" or the "wash-out." You will be able to see the shadow of the spars through the fabric. By practising this sort of thing you will, after a time, become quite expert, and will be able to diagnose by eye faults in efficiency, stability, and control.

SECTION III

THE PROPELLER

The propeller of the airplane is very similiar to the propeller of a vessel in many ways. It must have sufficient thrust, or pull in the case of a tractor, to overcome the resistance of the machine at its flying speed. The propeller itself introduces some resistance due to the skin friction as it revolves in the air, the resistance of the center of the propeller, eddies in the air caused by the whirling of the propeller and cavitation, or the tendency to produce a cavity or partial vacuum in which it revolves. This increases with the propeller speed and decreases the speed of the machine. For this reason propellers are often geared down from the engine so as to secure high power from the motor with the desired slower speed of the propeller. The pitch angle, or angle of incidence, of the propeller can be considered in much the same way as that of the planes, as the blades are in reality small planes which revolve instead of being forced straight through the air as with the wings of the machine.

The mechanical strength of the propeller blades is a serious consideration which affects the design very materially. For the propeller is subjected to very severe stresses due to the bending of the blades from the hub outward, the centrifugal force and also the shocks due to the impulses of the engine, even though these seem to be practically continuous in a multicylinder, high-speed engine. These impulses tend to loosen the propeller in its flanges and are credited with being the cause of charred hubs which are sometimes found when the propeller is taken off its shaft. These various problems demand great care in both design and manufacture, especially with the wooden propeller which is almost exclusively used at present. These are built up from layers of carefully selected wood, glued together with the utmost care and carefully shaped to templates which gage the exact contour at various points on the blade.

Propellers of all kinds, both for water and air service, have a certain amount of slip or lost motion. A propeller with a pitch of 10 feet, which means that would advance the machine

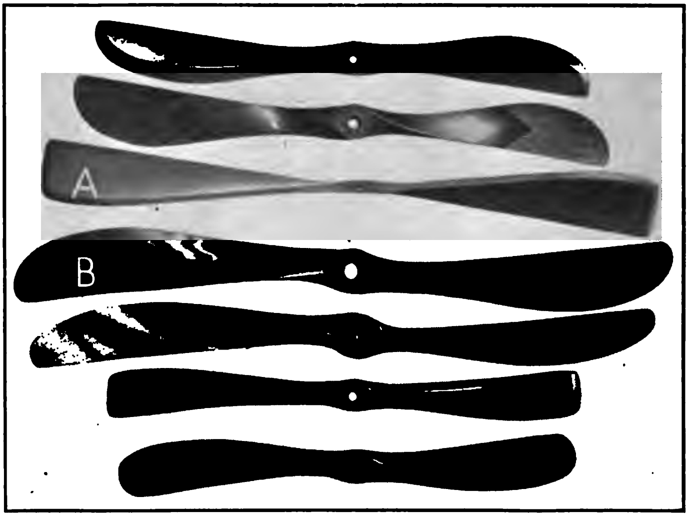


FIG. 19.—Types of propellers.

10 feet for every revolution if there were no slip, may advance only 7½ feet. This would mean a slip of 2½ feet of 25 per cent.

As the outer end of the propeller travels faster than the points nearer the center, the pitch angle changes just as is the case with a thread cut on a bar of steel. This can best be noticed on a small screw with a coarse pitch where it will be noticed that the angle at the bottom of the thread is much sharper than at the top.

A number of propellers of different designs are shown in Fig.

19. One of these is a very old design while *B* shows a modern propeller of the standard type. The center of the propeller is very ineffective and is largely dead resistance. To avoid this as much as possible Galladet mounts his propeller on a large annular hub which revolves on a ball bearing around the fuselage and behind the planes. This cuts out the center and merges it into the stream line of the fuselage itself. This method is said to be very satisfactory and it also allows the propeller to be geared down very easily.

PROPELLER IS MADE BY HAND

Among the many airplane parts that remain to be standardized is the propeller. A group of different styles is shown in Fig. 19. Here, propeller *A* is of very old design, while *B* is the type that is being used most largely at the present time. The other designs illustrate different ideas that have been tried out during the past few years. Propellers may be considered somewhat akin to the wing of an airplane, so far as the design of their surface is concerned. As we find the upper side of the wing convex, so we also find the front side of the propeller curved in the same way, while the back side is hollowed out somewhat in the manner of the under side of the airplane wing. When we add to this the constantly changing shape from the pit to the hub, we can see that it becomes a job for a skilled woodworker when the propellers are made by hand, as nearly all of them are at the present time. This shows two of the propellers with protecting tips on the ends of the blades. These tips are of thin sheet copper riveted in place.

Beginning with the actual manufacture of the propeller, we come to the laying out of the different pieces on the black-walnut board from which they are to be cut, as shown in Fig. 20. Black walnut is used very largely for this work, although in some cases it is alternated with layers of spruce, each layer being from ¾ to ⅞ inch thick. After the various pieces that are to be built up to form the propeller have been laid out, they are cut out on the band-saw, as shown. One of the long pieces is here shown being sawed into shape before gluing and building up.

In some places the propeller blades are roughed out on a sort of routing machine, using a form to guide the routing tools, but in most cases they are still worked out by hand from the rough built-up propeller blank. Great care must be taken in building up the layers that form the propeller, as it is absolutely necessary that there be a perfect union at all points of the surface.

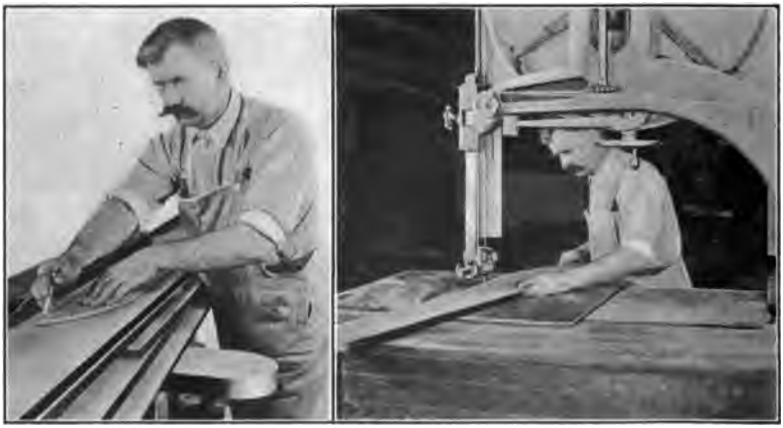


FIG. 20.—Laying out and sawing propeller laminations.

The parts to be glued must be thoroughly covered with a thin layer and then firmly held in position until absolutely dry. After this, the propeller is ready to be worked out by whichever method may be employed in the shop. In this case, nearly all the work is done by hand, Fig. 21 showing one end of a propeller cut almost to its proper shape and being tested by carefully made templets.

As can be seen from the tools on the workman's bench, the planes and draw-knives of various shapes are the main tools required. In addition to these a steel straight-edge, a level and a surface plate are necessary in testing the various parts of the propeller at frequent intervals. As shown, the propeller is supported on a central shaft, or peg, about which it can be turned so as to bring either end in position for measuring. This is an extremely interesting job and one requiring the utmost patience, as there can be very little variation allowed from the standard shape, length or width, and the matter of balance is of the utmost importance.

Fig. 21.—Testing shape of blade.

Fig. 22.—Testing balance of propeller.

Fig. 22 shows, in its final balancing stages, a propeller built of black walnut and spruce. This is a case of static balance, the propeller being very carefully mounted on knife-edges that actually can be leveled by special screws at each end. The propeller must stay in any position in which it is placed. The final balancing is secured by applying a light coat of varnish near the outer end, in many cases a mere touch of the varnish brush serving to supply all the extra weight that is necessary to put the propeller in perfect static balance. This is one of the points that is very strictly watched, as an unbalanced propeller can do much damage to the whole machine, as well as be a source of danger to the aviator.

Another design for securing greater efficiency of the propeller is that of Dr. Olmstead and shown in Fig. 23. This reverses the usual design of having the widest part of the blade near to outer end and makes the propeller widest at the hub. The pitch angle at the hub is very sharp and the blade tapers very rapidly from the hub to the outer end, the shape resembling a bird's wing in many ways. These propellers, as with all propellers in fact, have to be designed for the particular type of machine they are propel, the resistance and speed being the prime factors. In some cases these propellers are 24 inches thick at the hub and only 4 inches wide at the tip, making them very distinctive in every way. Tests show them to give very

Fig. 23.—Olmstead propeller.

good results but they are so radical that they have not been widely used as yet.

Having the design of the propeller for the given type of machine the drafting room makes templates of the proper shape and curve and shape of the blade at various points along its length. These gaging or contour points vary with different designs from 3 to 6 inches apart, 4½ inches being a good average. In this way the propeller maker is enabled to get the two blades almost absolutely alike, which is very essential for best results and in order to have the two blades balance when the propeller is finished.

The various boards or laminations which go to make up the propeller are cut to shape on the band saw, each being cut to pattern to use the minimum amount of material. Black walnut is considered one of the best woods for this purpose but spruce, maple and birch are also used. Black walnut and spruce are often used in alternate layers. These boards are then heated to prevent the glue drying too quickly, put together in the proper order and clamped in a heavy press until thoroughly dry. When the rough propeller comes out it looks about as in Fig. 24 and is then ready to be roughed out. This is usually done by hand with different forms of draw knives but is done with a routing machine in some of the larger shops. This leaves it in approxi-

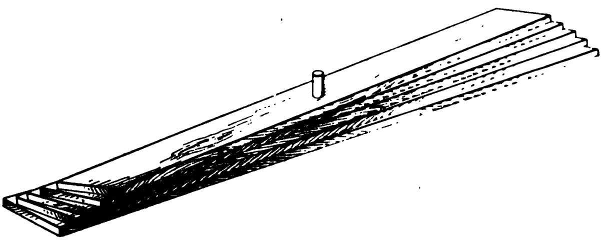


FIG. 24.—Propeller in the rough.

mately the correct shape and it is then finished, usually by hand, to the templates already mentioned.

TESTING THE SHAPE OF BLADES

In testing the various points the propeller is laid on an iron block having a central stud at right angles to it and which represents the propeller shaft. This allows the templates to be placed on the blades at the desired intervals, these intervals being marked on the iron plate itself. The angle of the flat or nearly flat surface can also be readily measured. A surface gage is also used very carefully to test the height of various portions of the blade from the testing plate on which it rests. The pitch of a propeller can be measured by reversing this process, *i.e.*, measuring the pitch angle at various points and laying these off on a chart. Such a chart should show a uniform change of pitch from the hub out. If it fails to do this, it indicates that the propeller has not been carefully measured and that it will not be efficient.

Some allow 1/8 inch out of straight for a propeller when it is mounted on a shaft and revolved past a given point, but most makers and users expect them to be nearer straight than this. The blade length should be correct and uniform within 7/16 inch and some do better than this, as balancing is a very important feature in propeller making. Horizontal ways are generally

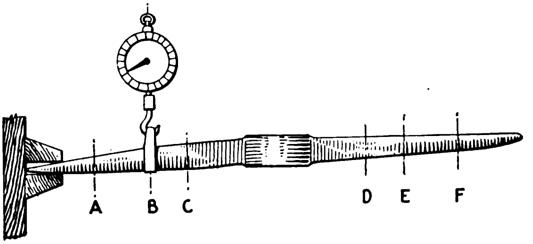


FIG. 25.—Testing uniformity of weight.

used although some mount the propeller on a shaft with a special ball bearing. This is done after the end is coppered, if it is to be so protected. The final balancing is done by putting a little more varnish on the light end of the propeller, which indicates how carefully shaped they must be.

A method of testing the propeller for uniformity of weight along its length is shown in Fig. 25. Here one end of the propeller is held loosely in an opening and the whole propeller suspended with a spring balance at different given points along its length. The propeller is then reversed and suspended in the same way from corresponding points on the other end. If the weights balance on both ends of the propeller, the centrifugal stresses should be practically equal and the propeller run satisfactorily.

It is also quite important that the surface areas of both ends of the propeller should be equal. This can be easily tested by measuring the width of the blades at given points on each end seeing how they compare. The joints are frequently tested by revolving the propeller at from 5 to 10 per cent. higher speed than that at which it will be run and then examining the joints carefully to be sure that none of them have started. These joints should not show glue as the wooden layers should be solid together.

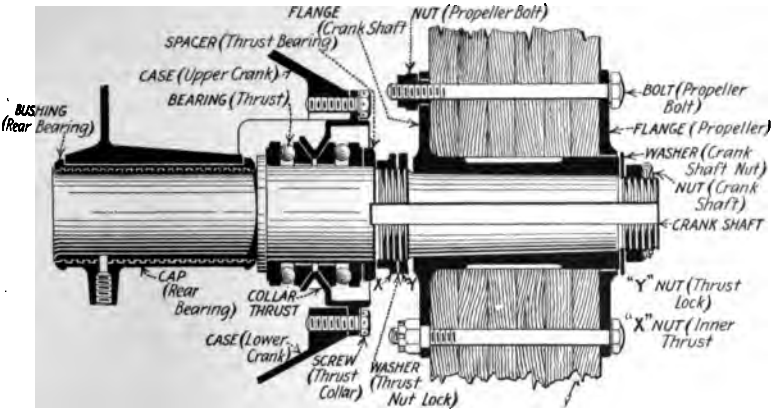


FIG. 26.—A typical propeller mounting.

The propeller surface should be very smooth particularly near the outer end where the speed is the greatest. When it is considered that the tips sometimes have a speed of 30,000 feet per minute, it can readily be seen how the surface affects the skin friction.

There are a great variety of propeller hub mountings, one of which is shown herewith in Fig. 26. This requires no explanation, as the methods of holding the propellers are clearly shown. It is very necessary that the propeller be mounted square and straight on the shaft and that it is securely fastened. This squareness can be tested in a similar manner to that already described for the straightness of the blades, by revolving it half way and measuring the position of the leading edge or some other point on each blade. A propeller is sometimes thrown out of squareness by having the bolts tightened up too much on one side. They should be tightened up gradually, going around the hub until bolts all have an even tension.

Propellers should receive the best of care as so much depends upon them and they are so easily affected by outside influences. They should be covered from the sun if the machine is to stand long in the open. Bags or covers are made from heavy cloth to slip over the blades and are tied with draw strings. They should never be stored in a damp place nor yet in a very dry place, as either condition affects the glue which holds the layers together. They should never be stored out of doors on account of both sun and rain.

The best method of storing is to hang them in a vertical position on a strong peg which goes through the shaft hole. It is not a good plan to lean them up against a wall or to hang in a horizontal position. The object is to avoid any stresses which will tend to get them out of shape in any way, as unless they are symmetrical and in good condition, they are not as efficient, they are apt to vibrate or "flutter" badly, and this has a bad effect on the engine and its bearings.

Four-bladed propellers are not largely used and then mostly in cases where the pitch is comparatively large. They are usually considered as being less efficient than the two-bladed propeller although in the case of the Gallaudet propeller previously referred to four blades are used very successfully. There is, theoretically at least, more interference in the disturbance of the air, where four blades are used. When one blade receives air which has already been set in motion by the blade preceding it, there is less reaction and consequently less efficiency.

Propellers must be watched carefully to detect splinters, cracks and other defects which might cause trouble. Bad landings usually damage a propeller as the machine is very apt to nose down and the propeller strikes the ground. While this usually breaks off one or both wings this is not always the case and after a propeller has dug into the ground it should be very carefully examined for defects of any kind.

Propellers of flying boats and seaplanes are often nicked and chipped by the particles of spray which strike the blades as they are starting or landing. The high speed of the propeller makes the spray strike a much harder blow than might be imagined. The same is true when the machine is flown in a sandy country, the sand cutting the blades quite seriously at times.

Copper protection strips, as shown in Fig. 19, are often riveted over the edges of propellers at the ends, this serving to protect the outer ends which are most apt to be damaged. The only objection to these is that they sometimes tear loose and have been known to cut guy wires and even the fuselage in the case of a pusher-type machine. In some instances protecting strips of canvas have been used for this purpose, being glued on the blades in the desired positions. These protect the blade fairly well and do less damage even if they loosen and fly off, which is not apt to be the case.

STANDARD HUB FOR AIRPLANE PROPELLERS

One of the important questions in connection with the building of large numbers of airplanes relates to the size, proportion and methods of fastening of the propeller hub. There are many kinds of propeller-hub fastenings in use, some with the multiple splines, which are not only difficult to make and fit, but which also effectually prevent the lapping of the taper on the engine shaft with the taper in the hub. They have also been more or less unsatisfactory in many ways.

The new standard hub adopted by the aviation section of the United States Army is shown in the accompanying illustration. This gives both the shape and the dimensions of the various parts of the hub and of the end of the engine shaft. These particulars

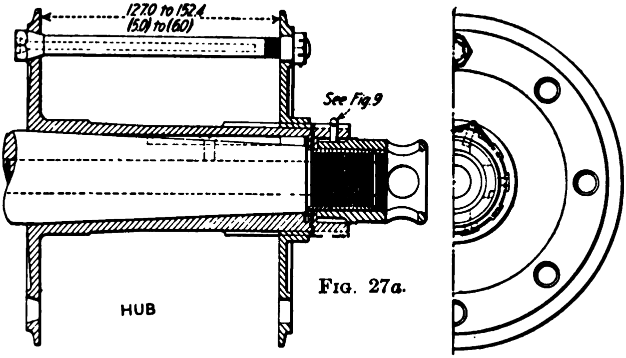


FIG. 27a.

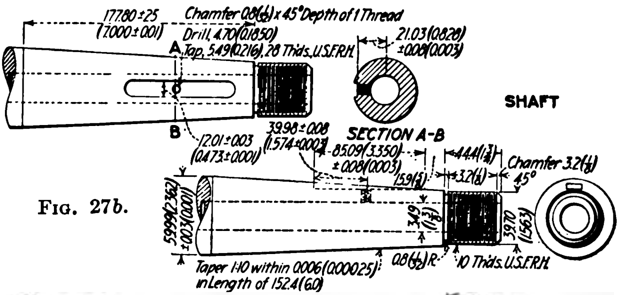


FIG. 27b.

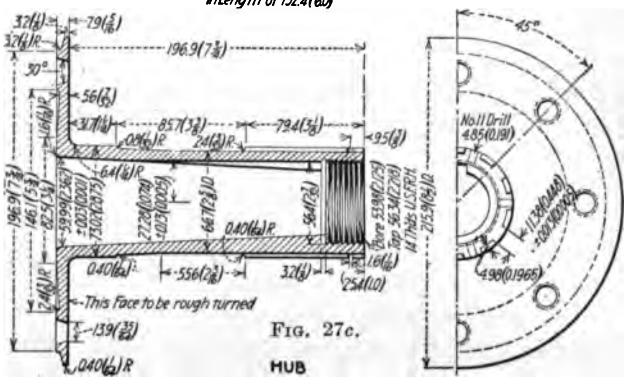


FIG. 27c.

FIG. 27a.—Assembly of hub. FIG. 27b.—Engine-shaft end. FIG. 27c.—Hub
FIGS 27a to 27c.—Details of standard propeller hub, 110 to 170 hp.

have been very carefully worked out as a result of experience both in this country and abroad. The illustrations, Figs. 27*a* to 27*i*, show the hub and shaft for propellers and engines of from 110 to 170 horsepower. As will be seen, the dimensions in most cases are given in both English and metric measurements.

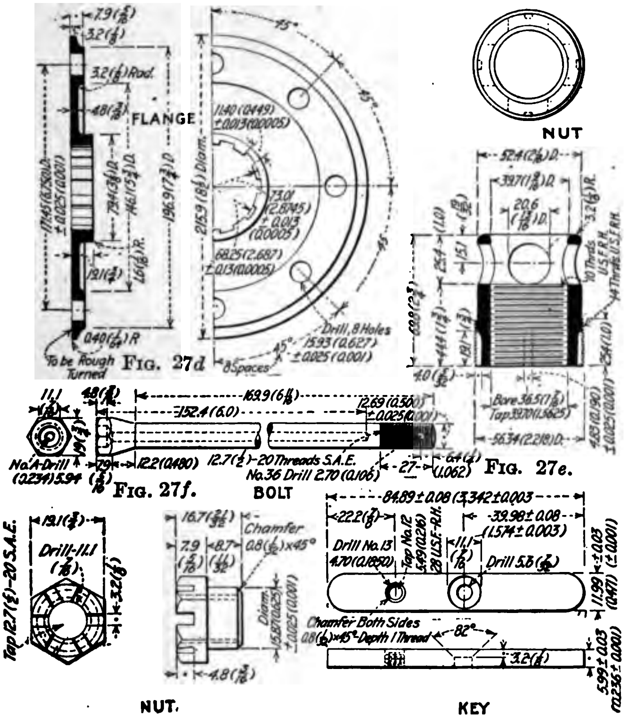


FIG. 27*g*. FIG. 27*h*.

FIG. 27*d*.—Flange. FIG. 27*e*.—Shaft nut. FIG. 27*f*.—Bolt. FIG. 27*g*.—Nut. FIG. 27*h*.—Key.

FIGS. 27*d* to 27*h*.—Details of standard propeller hub, 110 to 170 hp.

The shaft is given a taper of one in ten, and the hub is prevented from turning by a straight key held in place by a flat-headed standard A.S.M.E. machine screw. The hub is forced in place on the taper by the long nut by means of a bar put through

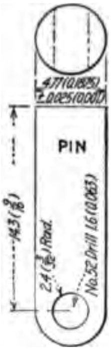


FIG. 27i.

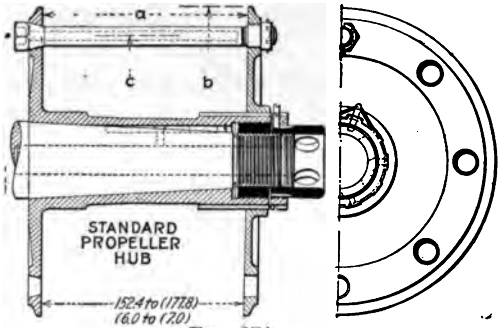


FIG. 27j.

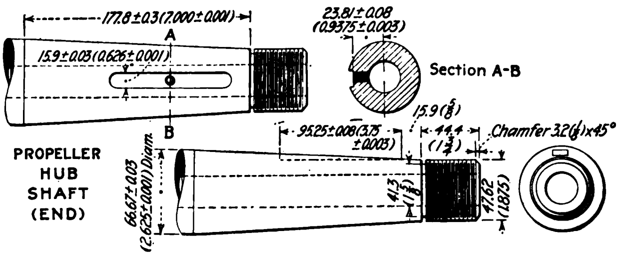


FIG. 27k.

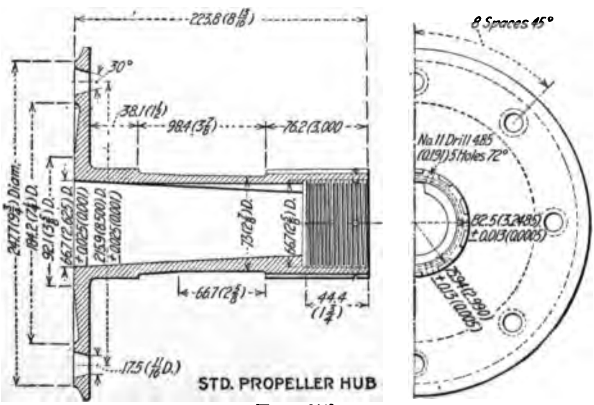


FIG. 27l.

FIG. 27i.—Locking pin. FIG. 27j.—Assembly of hub. FIG. 27k.—Engin shaft end. FIG. 27l.—Hub.

FIGS. 27i to 27l.—Parts of standard propeller hub.

the holes at the end of the nut, and the nut is then prevented from turning by the pin, which drops into one of the four slots around the circumference of the nut.

The inner flange is integral with the spool or barrel of the hub, but the outer flange has a movement of 1 inch, allowing for hub

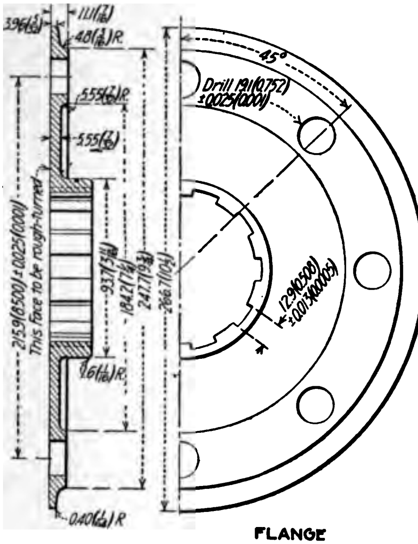


Fig. 27*m*.

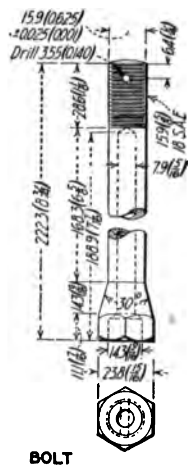


Fig. 27*o*.

Fig. 27*m*.—Flange. Fig. 27*o*.—Bolt.

Figs. 27*m* and 27*o*.—Parts of standard propeller hub, 170 to 250 hp.

Cotters for Bolts of Standard Propeller Hub

Diameter, In.	Length, In.	Drill for Bolt, In.
1/16	5/16 to 3/4	No. 48—0.076
3/32	1/2 to 1 1/8	No. 36—0.106
7/64	7/8 to 1 3/8	No. 30—0.1285
1/8	7/8 to 1 3/4	No. 28—0.140
9/64	1 1/4 to 2 1/4	No. 21—0.159
11/64	1 5/8 to 2 1/2	No. 11—0.190
13/64	2 to 3	No. 2—0.221

variations of from 5 to 6 inch in thickness. The outer flange is prevented from turning by ten splines; and as five of these splines

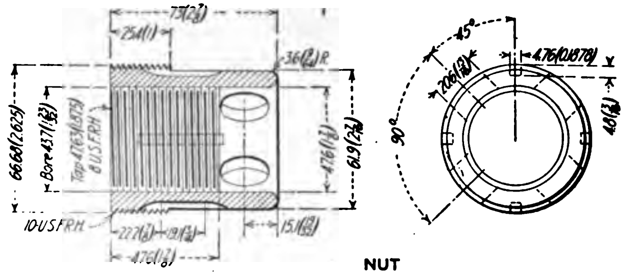
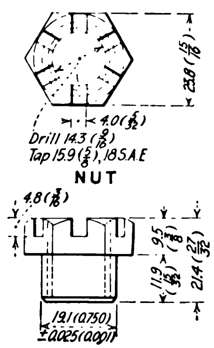


FIG. 28a.



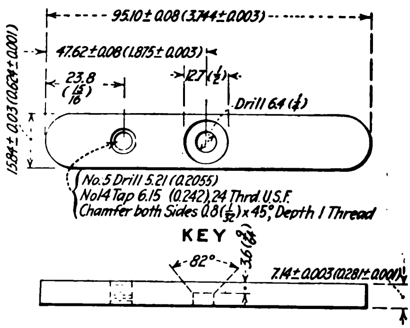


FIG. 28b. FIG. 28c.

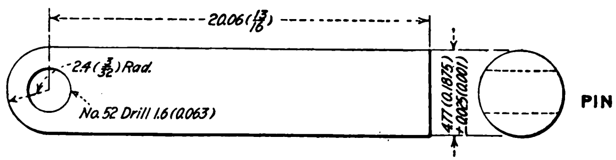


FIG. 28d.

FIG. 28a.—Shaft nut. FIG. 28b.—Nut. FIG. 28c.—Key. FIG. 28d.—Locking pin.

FIGS. 28a to 28d.—Parts of standard propeller hub, 170 to 250 hp.

are drilled to receive the locking pin, it gives a large number of positions in which the nut can be securely locked in place. This pin is held in position by a wire running through its head and around the hub, a groove being provided for this purpose. The ends are twisted together in the usual way.

The bolts have a taper head to insure a perfect fit in the inner flange, and the nut on the outer end has a projecting sleeve that goes through the outer flange, so that the thread of the bolt does not come in contact with the flange at any point. It will be noticed that the engine shaft is hollow and that the bolt is drilled for nearly its entire length. It will also be seen that the key has a tapped hole at the front end through which a screw can be used as a jack in lifting the key out of place, should it become jammed in any way.

Figs. 10 to 18 show the details of the standard hub for engines of from 170 to 250 horsepower.

TESTS OF PROPELLERS

To test the pitch angle the propeller is mounted on a shaft which is mounted at right angles to a beam which is straight

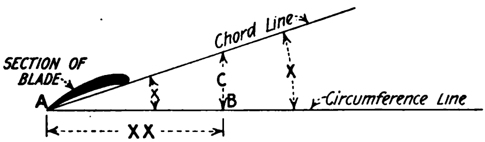


FIG. 29.—Laying out curve of propellers.

and true. Pick out some point on the propeller at any given distance from the center of the hub and find the angle the propeller makes with the beam at this point, by means of a protractor. Lay out this angle on a large sheet of paper as in Fig. 29, this being the chord of the pitch angle. The straight or base line must represent the circumference of the propeller at the face of the beam.

If this point is taken at 2 feet from the center we have a circle 4 feet in diameter or (4×3.1416) 12.5668 feet. Bring this down to any scale which is convenient, say 2 inches to the foot, and lay off the horizontal line 25.132 inches. Then the distance from this point on the circumference line to the chord line is the pitch at this point. This should agree with the specified pitch of the propeller, unless the propeller blade is distorted, due to faulty manufacture or the hole being in the wrong place. An error of a half degree is permissible but more than this should be reported. This test should be made at several points and the results carefully checked up. The length should also be tested by revolving past a given point; a difference of not over 7/16 inch is permissible. Balance is also essential and is tested by mounting on ball bearings on a carefully leveled runway or balancing way. It should remain in any position.

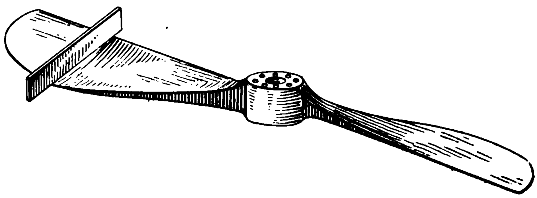


FIG. 30.—Testing curve of blade.

If it is out of balance appreciably it must be corrected as an unbalanced propeller will do a lot of damage to an engine and may wreck a plane. The test for weight at different points has already been given, as in Fig. 22. During this test the propeller must be kept horizontal, care being taken to have the different points the same distance apart on each side of the hub. The surface area can be easily calculated by measuring the width at several given points; these measurements should not vary over 1/8 inch at any point.

The camber or curve of the blade can also be tested quite easily on the concave side by passing a straight-edge along the blade as in Fig. 30 and noting the space at different points. On the convex side this requires a set of templates which can be readily made from the drawings of the propeller and may be worth while if there are enough of one kind to be tested occasionally.

The following suggestions for riggers is from the Royal Flying Corps manual.

NOTES ON RIGGING FOR AIR MECHANICS

Importance of Good Rigging.—It is impossible to exaggerate the importance of *care* and *accuracy* in rigging. The pilot's life, the speed and climb of the airplane, its control and general efficiency in flight, and its duration as a useful machine all depend upon the rigger. Consider that while the engine may fail the pilot may still glide safely to earth *but* if the airplane fails, then all is lost. The responsibility of the rigger is, therefore, very great, and he should strive to become a sound and reliable expert on all matters relating to his art—for an art it is, and one bound to become increasingly important as time passes.

Flight.—First of all he must have a sound idea of flight and stability.

Flight is secured by driving through the air a surface or surfaces inclined to the direction of motion. Such inclination is called the "angle of incidence.

Lift.—In this way the surfaces, that is the lifting planes, secure a lift from the air, and, when the speed through the air is sufficient, the lift will become greater than the weight of the airplane, which must then rise into the air.

Bear in mind that the drift is always trying to collapse the planes backward.

Thus you will see that there are four forces to consider. The *lift* which is opposed to the *weight*, and the *thrust* which is opposed to the *drift*. The lift is useful—the drift is the reverse of useful. The proportion of lift to drift is known as the *lift-drift ratio*. This is of paramount importance for upon it depends the efficiency of the airplane. In rigging an airplane the greatest care must be taken to *preserve the lift-drift ratio*. Always keep that in mind.

Angle of Incidence.—The angle of incidence is the inclination of the lifting surfaces. If the angle of incidence is increased over the angle specified in your rigging instructions then both the lift and the drift are increased also—and the drift is increased in greater proportion than the lift. If, however, the angle of incidence is decreased, then the lift and the drift are decreased and the lift decreases in greater proportion than does the drift. You see then that in each case the efficiency is spoiled, because the proportion of lift to drift is not so good as would otherwise be the case.

Balance.—The whole weight of the airplane is balanced upon, or slightly forward of, the center of the lift.

If the weight is too far forward then the machine is nose-heavy.

If the weight is too far behind the center of the lift then the airplane is tail-heavy.

Get a good understanding of the above before going any further.

ABOUT THE ENGINE

Although care of the engine is primarily the machinist's or engineman's job it is well for the rigger to know something about it as it often helps out in emergencies, and these are always arising in unexpected quarters.

As a rule, when the propeller is fitted to the crankshaft, it revolves in an anti-clockwise direction when viewing it from the position you stand in to swing it, or in front of the machine.

When it is fitted to another shaft (which is geared to the crankshaft) as in the case of the Renault and R.A.F. engines, then, as a rule, it revolves in a clockwise direction.

Following are some examples, and you will do well to add new engines to the list as they come into use:

Type		Name	No. of cylinders	Rotation of propeller
Stationary engines	120 hp.	Beardmore	8	Anti-clockwise
	100 hp.	R.A.F.	8	Clockwise
	100 hp.	Curtiss	8	Anti-clockwise
	80 hp.	Renault	8	Clockwise
	70 hp.	Renault	8	Clockwise
Gnome rotary engines	100 hp.	Monosoupape	9	Anti-clockwise
	80 hp.	Gnome	7	Anti-clockwise
	50 hp.	Gnome	7	Anti-clockwise
Rotary engines	100 hp.	Clerget	9	Anti-clockwise
	80 hp.	Le Rhone	9	Anti-clockwise

Starting the Engine

Sound Footing.—First of all make sure that the ground just in front of the propeller affords you a good sound footing. Should your foot slip when swinging the propeller it may result in serious injury for yourself.

Now place the blocks in front of the wheels, and lay out their cords toward the wing tips.

One air mechanic at each wing tip and grasping the bottom of the outer strut to steady the airplane when the engine is running. These air mechanics will pull the blocks away when the pilots signal for such action.

Not less than 2 air mechanics at the tail end of the fuselage in order to keep it *down* when the engine is running.

Rotary Engines.—In the case of rotary engines it is often necessary, *after ascertaining that the switch is off*, to dope the cylinders with petrol. This is done by squirting petrol through each exhaust valve. Great care should be exercised to make sure the squirt can is clean. Never lay it on the ground. The top of the petrol tin is a good and convenient place.

Switch Off.—Before attempting to rotate the propeller *always* make sure that the ignition switch is "off," *i.e.*, in its downward position. Otherwise the engine and propeller may start unexpectedly with disastrous results to yourself. There has been more than one fatal accident due to carelessness in overlooking this point.

Petrol on and Air Closed.—Now ascertain that the petrol is on and the air closed. The air is not really quite closed, but it is partly cut off so that the mixture may be rich in petrol in order to facilitate the first few explosions.

Rotate Propeller.—Now swing the propeller round. This will turn the engine, and the effect of the descending pistons will be to suck the mixture into the cylinders.

Contact.—Now sing out "contact" to the pilot. He will put the ignition "on" replying to you "contact."

Swing Propeller.—Now one good downward swing of the propeller blade and *stand clear*. If the engine fails to start ask the pilot to *switch off* and go through the same operation again.

"Danger of Backfire."—When swinging the propeller *be careful* to stand clear of it. There is often a possibility of the engine "backfiring" and suddenly turning the propeller the wrong way round. This is usually due to the ignition occurring early, *i.e.*, before the piston arrives at the top of the cylinder, and if the engine is revolving slowly the momentum of the moving parts (crankshaft, propeller, flywheel, etc.) may not be sufficient to carry it round in the right direction—the result being that the piston never gets to the top of its stroke but descends again driving the crankshaft back and round in the wrong direction. Any engine fitter will show you exactly how this works by means of turning round the crankshaft of a partly dismantled engine.

Signals.—1. The pilot, when ready to start, will wave his hand from side to side. This is the signal for the chocks under the wheels to be smartly pulled away by means of the cords attached to them.

2. Now the pilot waves his hand in a fore and aft direction. This is the signal for *everyone to stand clear without a moment's delay*, and is especially meant for the air mechanics at the tail of the fuselage.

The order of standing is as follows:

Pilot to Rigger...........	"Everything all right?"
Rigger..................	"All correct, sir." (Remember that "all correct" covers a lot, and that it is the rigger's duty to report anything not in *perfect* condition.)
Pilot to Machinist........	"Everything all right?"
Machinist...............	"All correct, sir."
Machinist...............	"Switch off?"
Pilot....................	"Switch off."
Machinist...............	"Gasoline on—air closed?"
Pilot....................	"Gasoline on—air closed." The machinist, now rotates the propeller. (In the case of a rotary engine it must first be doped with gasoline as explained above.)
Machinist...............	"Contact?"
Pilot....................	"Contact." The machinist now swings the propeller and *stands clear.*
Pilot....................	Waves hand sideways.
Air Mechanic............	Pulls blocks away from wheels.
Pilot....................	Looks at Senior Non-Commissioned Officer or Mechanic.
Senior Non-Commissioned Officer or Mechanic.....	Looks to see if all is clear for ascent and no other airplane descending. If all clear he salutes.
Pilot....................	Waves hand in a fore and aft direction.
Air Mechanic............	*Stand clear.*

The Engine.—Although you are a rigger, and not supposed to have a close knowledge of engines, it is highly desirable that you should have some idea of the way in which they work, the rotation of propellers, and the *precautions* and *rules* in respect of swinging the propeller.

Firstly, the engine. In each cylinder is a piston which is connected to the crankshaft (see examples in your squadron engine shop) so that, as the piston travels up and down the cylinder, the shaft is made to rotate.

As the piston travels down the cylinder the inlet valve opens and the piston sucks in a mixture of petrol and air, in much the same way as a syringe sucks in water. The petrol is vaporized and mixed with the proper proportion of air in the carbureter which is connected with the inlet ports of the cylinders by means of the inlet pipe.

The piston then rising, and the inlet valve having closed, it compresses the mixture, which is much more explosive when compressed.

The explosion takes place when the piston is at about the top of the cylinder, and it is caused by an electric spark between the points of the sparking plug. The electric current is generated by the magneto which is connected to the sparking plug by wires.

The force of the explosion drives the piston down and causes the crankshaft to rotate.

As the piston rises again the exhaust valve opens and the burnt gases are forced out.

The working of the engine may then be divided into four strokes of the piston, thus:

First revolution of crankshaft.....	1. Piston descends, sucking in mixture. 2. Piston rises, compressing mixture.
Second revolution of crankshaft	3. Explosion takes place, forcing the piston to descend. 4. Piston rises, forcing burnt gases out of exhaust valve.

Thus, an explosion takes place for every two revolutions of the crankshaft.

From this it can be seen that an engine with two cylinders can have them arranged so that an explosion takes place for every revolution of the crankshaft, and, in this way, more even running of the engine is secured.

As a matter of fact this idea is carried still further and engines are constructed as a rule with four cylinders, or even six, eight, or twelve cylinders, the result being as follows:

1 cylinder	1 explosion to	2	revolutions	of shaft.
2 cylinders	1 explosion to	1	revolution	of shaft.
4 cylinders	1 explosion to	½	revolution	of shaft.
8 cylinders	1 explosion to	¼	revolution	of shaft.
12 cylinders	1 explosion to	⅙	revolution	of shaft.

Similarly inlet, compression, exhaust and explosion take place every two, one, one-half, one-fourth or one-sixth revolution of the shaft, according to the number of cylinders.

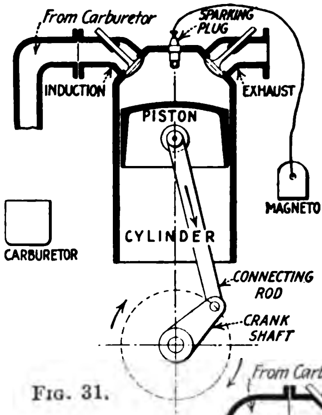


FIG. 31.

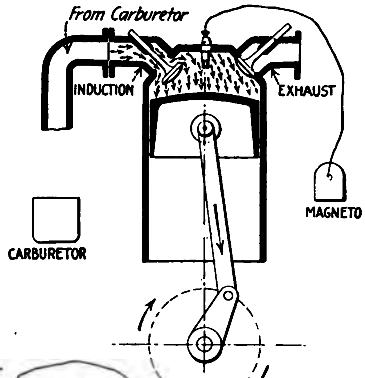


FIG. 32.

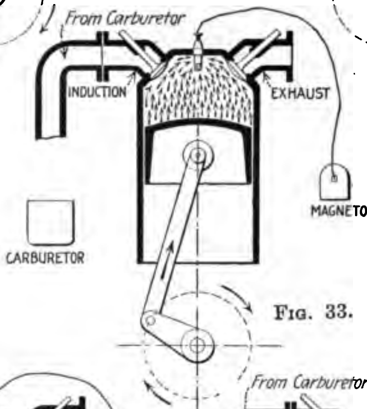


FIG. 33.

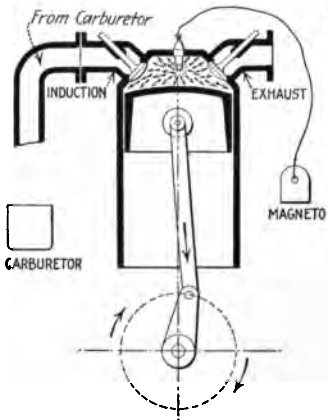


FIG. 34.

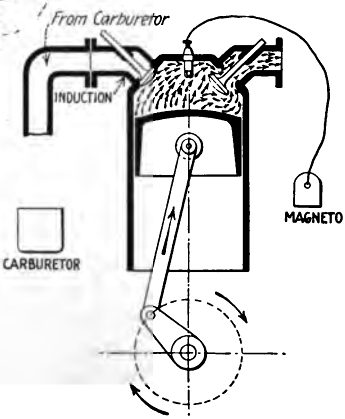


FIG. 35.

FIGS. 31 to 35.—**Diagrams of internal combustion engines.**

The compression can be readily felt by turning the engine by means of the propeller, but *care must* be taken to see that the ignition is off or an unexpected explosion may take place.

The diagrams, Figs. 31 to 35, are simply made to show how the engine works and actual examples can be seen in the squadron workshops. The parts are named in Fig. 31, to make this clear in every respect. As the piston travels down the cylinder, Fig. 32, the inlet valve opens and the piston sucks in a mixture of gasoline and air. The gasoline is vaporized and mixed with the right proportion of air by the carbureter through which it passes. When the piston comes up, Fig. 33, the inlet valve is closed and the charge is compressed, making it much more explosive. In fact if it is compressed enough it will explode of itself.

When the piston is almost at the top of its stroke, Fig. 34, the magneto sends an electric spark through the spark plug and ignites this explosive

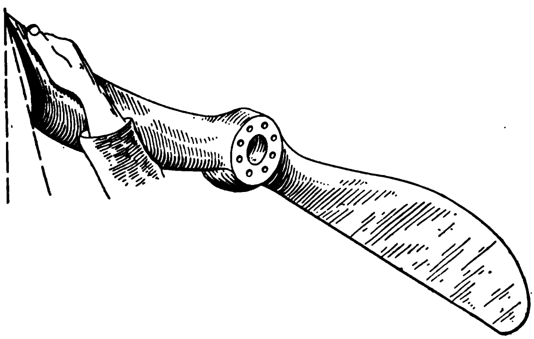


FIG. 36.—How to swing propeller.

charge which drives the piston down and rotates the crankshaft. On the next rise of the piston, Fig. 35, the exhaust valve opens and the burnt gases are forced out of the exhaust. This may be divided into the cycles of the two revolutions necessary to secure a power impulse, as follows:

First Revolution.—Downstroke piston draws in explosive mixture.

Upstroke, compresses mixture, ready for firing.

Second Revolution.—Piston forced down by explosion. Upstroke forces out burnt gases. This gives one explosion in each cylinder for each two revolutions, or four power strokes per revolution for an eight-cylinder engine. The more cylinders the more explosions or power impulses per revolution.

Care should be taken in swinging the propeller to always stand clear of an unexpected explosion or starting of the engine. The compression can be felt as it is turned by hand, but it is safer to have the ignition switch off unless it is desired to start the engine.

The shape of the propeller will readily show which way the engine is to be run as the propeller always screws into the air, no matter whether it is a tractor or a pusher. Then too, the trailing or back edge is always the thin edge as with a wing. Grasp the thin or trailing edge of the propeller and move it slightly to feel the compression. Fig. 36 shows how to take hold of the blade.

Propeller.—Before swinging the propeller (*i.e.*, rotating it to start the engine) it is necessary to know in which *direction it should be turned.*

Unless the propeller has been fitted to the engine incorrectly, it is quite easy to see in which way to turn it.

You must grasp the trailing edge of the blade and you will know it for the trailing edge because it is always much thinner than the leading edge. Move the propeller slightly so that you may "feel" the compression. The rotation of the propeller will now be in such a direction that the flattest side of the blade will engage the air and press against it thus:

Pitch.—The pitch is the distance the propeller will screw through the air in one revolution, supposing the air to be solid. As a matter of fact the air is not solid, and gives back to the thrust of the propeller blades so that the propeller does not travel its full pitch. Such "give-back" is known as *slip*. For instance, the pitch of the propeller may be perhaps 10 feet, and the propeller may have a slip of 2 feet. The propeller would then be said to have 20 per cent. slip.

To test the pitch angle the propeller is mounted on a shaft, the latter being mounted upon and at right angles to a beam. The face of the beam must be perfectly straight and true.

Now select a spot some distance (say about 2 feet) from the center of the propeller and, by means of a protractor, find the angle the chord of the blade makes with the beam. Then lay out the angle on paper thus:

The line marked *chord* represents the chord of the propeller. The line marked *circumference* represents the face of the beam. The angle the two lines make is the angle you have found by means of the protractor.

We will suppose, for the sake of example, that the point at which you have taken the angle is 2 feet from the center of the propeller. Find the circumference at that point by doubling the 2 feet (which is the radius) and then multiplying the result by 3.1417, thus:

$(2 \times 2) \times 3.1417 = 12.5668$ feet, *i.e.*, the circumference at that part of the propeller. Bring it down in scale, and mark it off from the point *A* and along the circumference line. Now draw the line marked pitch from *B* (the end of the circumference measurement of 12.5668 feet) and at right angles to the circumference line (see Fig. 29).

The distance from the base line to the chord line is the pitch of the propeller at that point (see Fig. 37).

It must agree with the specified pitch of the propeller which should be marked on the hub. If it does not do so then the pitch angle is wrong. This may be due: (1) to the propeller blade being distorted; (2) to faulty manufacture; or (3) to the hole through the boss of the propeller being out of place.

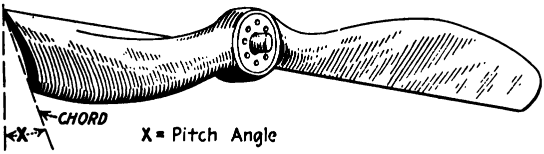


FIG. 37.—Pitch angle of propeller.

Degree of Error Allowed.—You may allow an error up to half a degree more or less of the correct angle, but if it is greater than that you must report the matter.

The propeller should be tested as explained above at points along the blades, the first point about 2 feet from the center of the boss and the others about a foot apart.

Length.—The propeller should be carefully tested to make sure the blades are of equal length. There should not be a difference of more than $\frac{1}{16}$ inch.

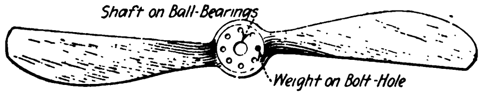


FIG. 38.—Testing balance of propeller.

Balance.—The prevailing method of testing for balance is as follows. Mount it upon a shaft. The shaft must be on ball bearings. Place the propeller in a horizontal position, and it should remain in that position.

If a weight of a trifle over an ounce placed in a bolt hole on one side of the boss fails to disturb the balance, then the propeller is unfit for use, as in Fig. 38.

The above method does not, however, test for the balance of centrifugal force, which comes into play as soon as the propeller revolves.

The test for centrifugal balance is as follows:

The propeller must be kept horizontal, and while in that position, weighed at any fixed points, such as *A*, *B*, *C*, *D*, *E*, and *F*, and the weights noted.

Now reverse the propeller and weight at each point again. Note the results. The first series of weights should correspond to the second series, thus:

Weight *A* should equal weight *F*.
Weight *B* should equal weight *E*.
Weight *C* should equal weight *D*.

There is no official ruling as to the degree of error allowed, but if there is any appreciable difference the propeller is unfit for use. The points *A*, *B* and *C* must, of course, be exactly the same distance from the center of the propeller as the points *D*, *E* and *F* (see Fig. 25).

Surface Area.—The surface area of the blades should be equal. Test with calipers, as in Fig. 39.

There is no official ruling as to the degree of error allowed. If, however, there is an error of over ⅛ inch, the propeller is really unfit for use. The points *A*, *B*, *C*, *D*, *E* and *F* must, of course, be exactly the same distance from the center of the propeller as the points *G*, *H*, *I*, *J*, *K* and *L*.

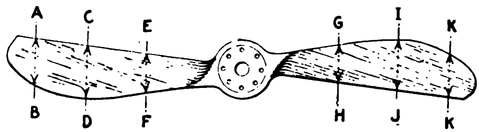


FIG. 39.—Measuring propeller surface.

Camber, i.e. (Curvature).—The camber of the blades should: (1) be equal; (2) it should decrease evenly toward the tips of the blades; and (3) its greatest depth should, at any point of the blade, be at about the same proportion of the chord from the leading edge, as at other points.

It is difficult to test the top camber without a set of templates, but a fairly accurate idea of the concave camber underneath the blade can be secured by slowly passing a straight-edge along the blade—the straight-edge (a steel rule will do) being held at right angles to the length of the blade and touching both leading and trailing edges, thus:

The concave curvature can now be easily seen, and, as you pass the straight-edge along the blade, you should look out for any irregularities of the curvature which should gradually and evenly decrease toward the tip of the blade.

Straightness.—To test for straightness mount the propeller upon a shaft. Now bring the tip of one blade around to graze some fixed object. Mark the point it grazes. Now bring the other tip round and it should come within ⅛ inch of the mark. If it does not do so it is due: (1) to the propeller being distorted; or (2) to the hole through the boss being out of place. In either case it is unfit for use.

The Joints.—The method for testing the glued joints is by revolving the propeller at 5 to 10 per cent. greater speed than it will be called upon to make in flight, and then carefully examining the joints to see if they have opened. It is not likely, however, that you will have the opportunity of making this test. You should, however, examine all the glued joints very carefully, trying by hand to see if they are quite sound. Suspect a propeller in which the joints appear to hold any thickness of glue. Sometimes the joints in the boss open a little, but this is not dangerous unless they extend to the blades as the bolts will hold them together.

Condition of Surface.—The surface should be perfectly smooth, especially toward the tips of the blades. Some propeller tips have a speed of over 30,000 feet a minute, and any roughness will produce a bad drift or resistance and spoil the efficiency of the propeller.

Mounting Propeller.—Be careful to see that the propeller is mounted quite straight on its shaft. Bring the tip of one blade round to graze some fixed object. Mark the point it grazes. Now bring the tip of the other blade round to the mark, and it should be within 1/8 inch of it. If it is not within 1/8 inch of the mark it is due to either the propeller being faulty in which case it should not be used, or it may be due to some of the propeller bolts being too slack or others being pulled up too tight.

Care of Propellers.—The care of propellers is of the greatest importance, as they are very likely to distort and lose their correct pitch angle and straightness.

1. Do not store them in a very damp or a very dry place.
2. Do not store them where the sun will shine upon them.
3. Never leave them in a horizontal position or leaning up against a wall.
4. They should be hung on pegs, the latter at right angles to the wall, and the position of the propeller should be vertical.

If the points I have impressed upon you in these notes are not attended to you may be sure of the following results:

1. Lack of efficiency, resulting in less airplane speed and climb than would otherwise be the case.
2. Propeller "flutter," *i.e.*, vibration, which will cause the propeller to distort and possibly collapse.
3. A bad stress upon the engine shaft and its bearings.

NOTE.—If engine vibration is complained of it may be due to a faulty propeller, or to the propeller not being straight on its shaft.

TORQUE OR TURNING EFFECT OF PROPELLER

The turning of the propeller produces a tendency to turn the whole airplane around in the opposite direction to that in which the propeller is running. This tendency was very marked in some of the earlier machines, especially the small monoplanes. This is overcome in some machines by increasing the angle of incidence of the plane on the side which would tend to tip down and in some cases to decrease the angle of incidence on the other side. By so doing there is more lift on one side of the machine than on the other which corrects the tendency to turn around the center line of thrust. Dividing this variation between

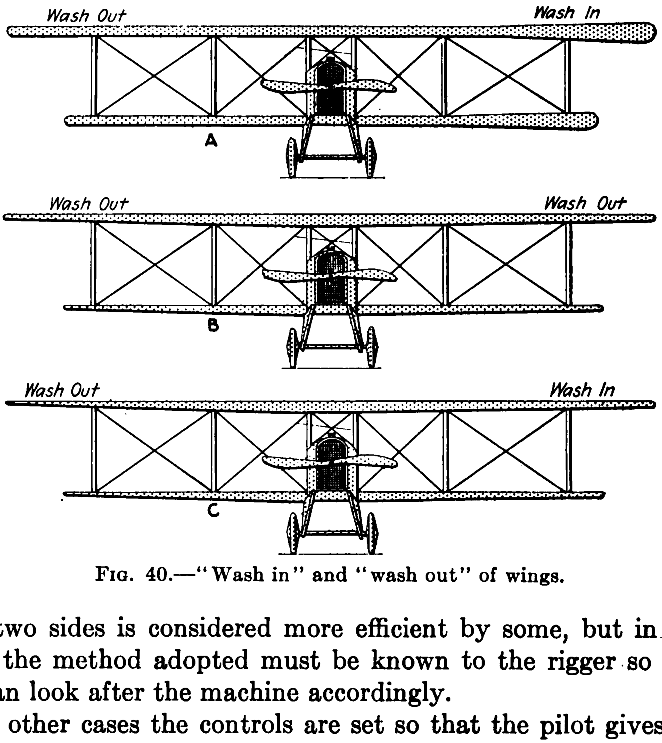


FIG. 40.—"Wash in" and "wash out" of wings.

the two sides is considered more efficient by some, but in any case the method adopted must be known to the rigger so that he can look after the machine accordingly.

In other cases the controls are set so that the pilot gives the ailerons on one side a little more angle than on the other. With the stick control on some machines the stick is set at a slight angle so that when the pilot holds it central, the ailerons are deflected enough to compensate for the turning tendency. On the training machines this offset is about ¾ inch at the upper end of the stick.

Two terms which are used in this connection are "wash in" and "wash out." When the angle of incidence increases from the center to the end of the plane it is called "wash in" and when it decreases from the center to the ends it is called "wash out." This is made clear in *A*, *B* and *C*, Fig. 40. In the last figure both sides are "wash out" with regard to the normal angle of incidence, but the right-hand end is "wash in" with regard to the left end, that is there is more increase at the end of the right wing than at the end of the left.

SECTION IV

WIRING THE PLANE

The wiring of an airplane is not less important than the care of the woodwork and the connections. In fact it is difficult to say which part of the whole machine is the most important. As with the woodwork it is advisable to study the methods used in wiring and fittings, this being a real mechanical problem from every point of view. The turnbuckle is almost universally used so that the tension on any wire may be adjusted to suit the machine or any changing conditions. These need little explanation being simply specially designed and made, right and left-hand screw-eyes with a connecting nut in the center in the shape of a long barrel. These are of steel and the threads should be a good fit in the barrel. They should not be very tight nor yet so loose as to make a poor fit and possibly strip

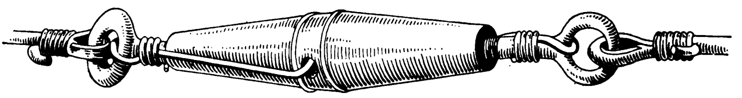


FIG. 41.—Wiring turnbuckle to prevent unscrewing.

the thread under tension. Turnbuckles are all locked in position by a soft locking wire (usually copper or brass) so that the barrel cannot unscrew, even a portion of a turn. This can readily be done by noting which way the barrel must turn to loosen and then twist the wire through the hole in such a way that it is held against turning in this direction. Fig. 41 shows how this can be done.

The rigger must learn to distinguish between the different kinds of wire for different purposes and between the grades which are good and those which are unsuitable for use in various places. He should learn the different kinds and sizes of loops and their fastenings, the right and wrong ways of making loops and the reasons for both. Standard loops have recently been adopted by the Society of Automotive Engineers are shown later together with the table which accompanies them. It will be noted that the ferrule is now made of coil wire instead of sheet metal as was the practice only a short time ago. These ferrules are wound up over suitable mandrels in long strips and cut off to suit, ten coils being the length advised in most cases. These are more satisfactory in every way as the sheet-metal ferrule was quite apt to split and release the wire of the loop. There

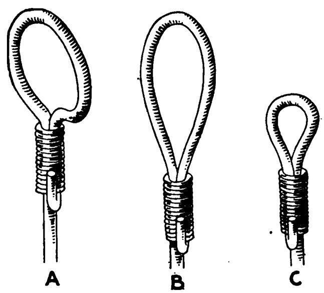


FIG. 42.—Good and bad wire loops.

is some difference of opinion as the advisability of soldering these ferrules but the tendency is to leave them without solder. This is on account of the necessity of using some kind of an acid or soldering paste and the danger of corrosion from this source. The joints are all covered with some waterproofing compound to prevent moisture gathering inside the ferrule.

These loops are necessary whenever a wire is connected to a fitting or to a turnbuckle and this means that a large number are used in every machine. For this reason it is advisable to become expert in loop making as soon as possible, as this will save much time when it comes to fitting up a machine or to repairing damages. One of the first requirements of a looped connection is that it shall not slip and so change the length of the wire connecting two points as this materially affects the tension and may throw one or more parts completely out of balance.

The best loops, according to English practice, have well-defined shoulders as shown at *A*, in Fig. 42 which effectually prevent the ferrule from slipping up and allowing the wire to lengthen. This also means that the loop should be as small as possible to go into the desired fitting to avoid its flattening or elongating under stress and so changing its length. Bearing this important feature in mind it is easy to see why the loop shown at *B* is not good. The loop is altogether too large and will flatten as soon as it is tightened as at *C*. Then too, there is no shoulder and the free side will pull through the ferrule, shortening the loop very materially and also stressing the wire by this short bending around the edges of the fitting through which it passes. Turnbuckles and all fittings which are concealed by the fuselage and planes should be well protected against rust by special varnish and are usually wrapped with tape. It is also important to know the qualities of wire, which must not be too hard or too soft. A practical test is as follows:

Take three pieces of wire of the same gage and about a foot long, selecting one which is too soft, one too hard and the third of the right quality. Clamp in a vise near a window, polishing the wires so as to show light reflections more clearly.

Bend the wire over sharply and as far as possible. The soft wire will flatten out somewhat as can be told by noting that the band of light on the wire has broadened out at the bend. The hard wire will probably show slight cracks or a roughness of the surface which is the beginning of cracks to be developed later. The right wire will show a slightly broader band of light but will not show the slightest roughness of surface. Repeating this experiment a few times will show you the good and bad wire and will prove helpful in many ways.

Here again the Manual of the Royal Flying Corps will prove of value.

No wire should be used which is damaged in any way. That is to say, it must be *unkinked, rustless, and unscored.*

The wire must be kept in good condition. Where the outside wires are concerned they should be kept well greased or oiled, especially where bent over at the ends. In the case of internal bracing wires which cannot be reached for the purpose of re-greasing them, they can be prevented from rusting by painting. Be very careful to see that the wire is perfectly clean and dry before painting. A greasy fingermark is sufficient to stop the paint from sticking to the wire. In such a case there will be a little space between the paint and the wire. Air can enter there and cause the wire to rust under the paint.

Tension of Wires.—The tension to which you adjust the wires is of the greatest importance. All the wires on the airplane should be of *the same tension*, otherwise the airplane will quickly become distorted and fly badly. As a rule the wires are tensioned too much. The tension should be *sufficient to keep the framework rigid.* Anything more than that spoils the factor of safety, throws various parts of the framework into undue compression, pulls the fittings into the wood, and will, in the end, *distort the whole framework* of the airplane.

Only experience can tell what tension to employ and assist in making all the wires of the same tension. Learn the construction of the various types of airplanes, the work the various parts do, and cultivate a touch for tensioning wires by constantly handling them.

Wires with no Opposition Wires.—In some few cases there are wires having no opposition wires or wires pulling in the opposite direction. In such cases be *extremely careful* not to tighten such wires beyond taking up the slack.

They must be a little slack, as otherwise they will distort the top spars downward. That will spoil the camber (curvature) of the plane and result in changing both the lift and drift at that part of the plane. Such a condition will cause the machine to lose its directional stability and also to fly one wing down. This matter of tension is of the utmost importance.

Wire Loops.—Wire is often bent at the end in the form of a loop. These loops, even when made perfectly, have a tendency to elongate, thus spoiling the adjustment of the wires.

Great care should be taken to minimize this as much as possible. The rules to be observed are as follows:

1. The size of the loop should be as small as possible within reason. By that I mean that it should not be so small as to create the possibility of the wire breaking.

2. The shape of the loop must be symmetrical.

3. The loop should have good shoulders in order to prevent the ferrule from slipping up. At the same time the shoulders should have no angular points.

4. When the loop is finished it should be undamaged, and it should not be, as is often the case, badly scored.

Stranded Wire Cables.—No splice should be covered with twine or other wrapping until it has been inspected and passed by whoever is in charge of the work. When a strand becomes broken the whole cable should be immediately replaced with a new cable. Control cables wear out where they run around pulleys and any sign of fraying should be attended to at once. The cables should be inspected after every flight, particularly where they run around the pulleys and nothing but good cable ever used on the machine.

The Society of Automotive Engineers have given much careful attention to this subject of wires, cables and fittings and have adopted as standards, the sizes and proportions which seem to have worked out well in practice. These follow in the next section.

STRESSES IN WING WIRING

The ordinary set of biplane wings is trussed together by wires in its three dimensions, making it into a pure box girder, but owing to the peculiar functions of an airplane's wings the different wires employed serve widely different purposes.

It is understood that it is the function of the wings to lift the airplane as a whole. Most of the weight is concentrated in the body, and therefore the problem really is how to transmit the lift exerted by the wings to this portion of the airplane.

It will be seen from Fig. 43 at *A*, that when the machine is progressing through the air, the lift exerted on the wings will endeavor to force them upward, while the weight in the nacelle tends to force them downward at the center. The net result is that the wings try to fold up from the tips inward. The bracing wires prevent this, however. The upward pull of the upper spars puts the lift wire *A* in tension. The lift on the lower spars puts the interplane struts into compression, the top spars being in compression and the lower spars in tension.

This being the case, there should be no load on the opposing diagonal wires *B*, when the machine is in the air. They come into play as the machine alights and loses its lift, and are therefore known as landing wires. With the machine resting on the ground the whole position is reversed, the landing wires *B* being in tension and the flying wires *A* slack. The top spars are then in tension and the bottom spars in compression. The interplane struts remain in compression all the time.

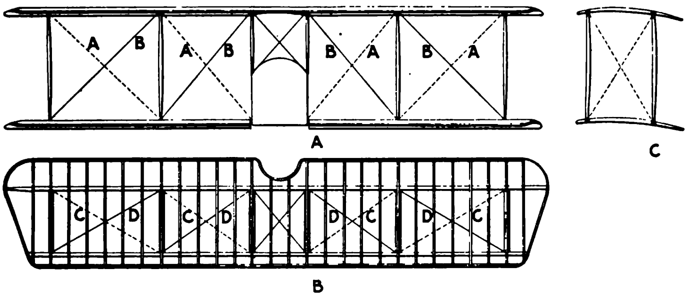


FIG. 43.—Stresses in wiring.

An airplane wing is not merely subjected to the reaction of lift, but also to the reaction of drift or resistance. That is to say, the pressure of the air on the machine as it travels through the air reacts in a horizontal sense and tries to fold the wings backward as well as upward. Here the horizontal bracing comes into play as in Fig. 43 at *B*. The wires *C* (known as drift wires) prevent the rear spar from bending backward, and the compression struts hold the front spar at the correct distance. The opposing diagonal wires *D* (known as anti-drift wires) take the strain when the machine is subjected to a sudden loss of forward way, as for example when landing on rough ground.

The spars are also subjected to a bending moment between each pair of supports, which is at its maximum at the center point between the supports and runs progressively to zero at the actual points of support.

Many airplanes are also fitted with external drift wires running to some point at the front of the machine, and external anti-drift wires running to the rear.

The third dimensional bracing serves to hold the upper and lower planes parallel to one another and in correct relation to the rest of the machine (see Fig. 43 at *C*). The change of center of pressure on the wing curve modifies the relative loads placed on each member of a pair of these wires, which are known as incidence wires.

It should be clearly understood that the stresses imposed on the different wires described as merely those of normal flight. Under peculiar circumstances, both in the air and on the ground, the spars, struts and wires may be called upon to resist stresses of a much more complicated nature, so that adequate strength must be given to each member.

SECTION V

AIRPLANE STANDARDS OF THE S. A. E.

In all the standards proposed by the Society of Automotive Engineers it has been the desire to make as few changes from existing practice as possible and to avoid specifications which would in any way delay production. This is shown in their handling of the matter of loops, turnbuckles, shackles and shackle pins. In the case of turnbuckles, for example, they have not attempted to specify the exact diameter of the shank, the pitch of the thread or the exact dimensions of the barrel. The turnbuckle should be a standard length between the eyes and to be sufficiently standardized so that the product of one maker can be substituted for that of another in case of necessity. The same thing applies to the fittings to which these turnbuckles are attacked, whether this is a wire or a clip. The same is true of shackles and clip ends and for the same reasons.

In the case of rod end or shackle pins they have been made as nearly like the present standards as seemed wise. The heads have been left thinner as this is found to be equally effective. The hole is made as large as is safe on account of its being easier to drill. The end of the pin is rounded, the "TD" meaning "tooling dimension" and is not intended as a gaging point as is the fillet under the head. The exact sizes of these is not important.

The bolt dimensions are the result of tests at the Curtiss plant. These tests included both untreated and heat-treated bolts, the material being 3½ per cent. nickel steel in each case. Tests showed that the untreated bolt should be 10 per cent. thicker than the heat-treated bolt but to allow for differences in heat treatment they recommend that the heads of heat treated bolts be ½ *D* plus 1/32 inch, the addition to cover very small bolts.

In the same way the nuts are made thicker than is necessary in ordinary practice to allow for the wear in the thread fit on account of the frequent putting on and taking off to which they are subjected in making adjustments and replacements. These should be a good fit without being tight, from 0.002 to 0.0025 inch being considered a fair tolerance between the thread on the bolt and the thread in the nut. The standards suggested are as follows:

Fastening Hard Wires.—The present British standard for fastening hard wires is shown in Fig. 44, the thimble being of wire wound in an oval as shown. The wire is slipped through this thimble, the end bent and the end threaded back through the thimble and bent over against the thimble. The whole thing is then soldered with a non-rusting paste. The table gives the dimensions recommended.

Galvanized Non-flexible Cable Ends.—Fig. 45 shows the method recommended and the table gives dimensions to be followed. The total length of the splice is shown by *L*, the two spaces dividing it into three approximately equal parts. The sizes of the winding wires are shown in the illustration.

Splices for Flexible Cable Ends.—The length of the splice from the pointed end of the opening in the thimble is represented by "splice plus or minus ⅛ inch." The end of the splice is wrapped or "served" with shellaced harness thread. Dimension *A* represents the distance from the end of the opening of the thimble to the end of the "serving." The table with Fig. 46 gives full dimensions.

Thimbles For Wire Ends.—The proposed sizes are shown in Fig 47 together with the table of sizes of various portions of the thimble.

Turnbuckles.—This gives the main dimensions for long and short turnbuckles together with their general appearance (Fig. 48).

Clip Ends.—The general proportions and dimensions for clip ends are shown in Fig. 49. The dimension *A*, which is the width of the arm, depends on the material to which the clip is welded.

Shackles.—The shackle shown in Fig. 50 is formed from a steel forging and the main dimensions are given on page 72.

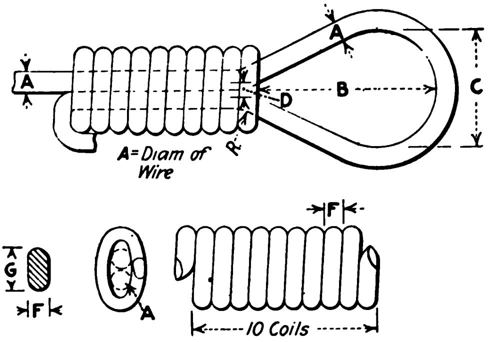


FIG. 44.—Fastenings for hard wire.

LOOPS

Size of wire *A*	Large loop 0.128	Small loop 0.128	0.102	0.081	0.064
B.	9/16	7/16	15/32	13/32	13/32
C.	23/64	17/64	9/32	17/64	17/64
D.	5/64	1/16	1/32	1/32	1/32
R.	13/64	9/64	9/64	9/64	9/64
FERRULES					
E.	0.114	0.114	0.091	0.072	0.057
GAGES					
F.	0.130	0.130	0.104	0.083	0.066
G.	0.260	0.260	0.208	0.166	0.132

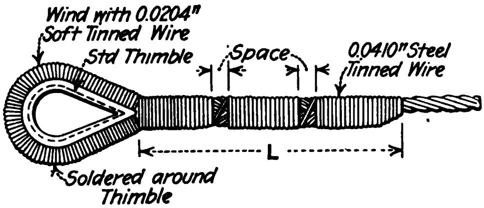


FIG. 45.—Non-flexible cable ends.

Diameter of cable, inches	Number of strands	No. wires per strand	*L*	Space	Wind	Full strength of cable, pounds
1/16	1	19	1½	⅛	1	500
3/32	1	19	2	⅛	1¼	1,100
⅛	1	19	2½	⅛	1½	2,100
5/32	1	19	2¾	⅛	2	3,200
3/16	1	19	3	3/16	2¼	4,600
7/32	1	19	3½	3/16	2¼	6,100
¼	1	19	4	¼	2½	8,000

NOTE.—Solder without drawing temper of wire. Loop portion served with 0.0204-inch soft-steel tinned wire before thimble is inserted.

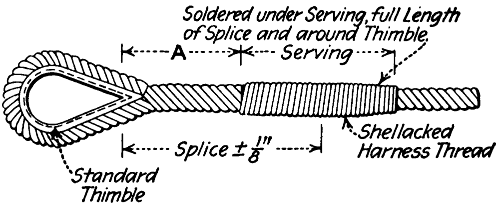


FIG. 46.—Flexible cable ends.

Diameter of cable, inches	Number of strands	No. wires per strand	Length of splice	Length of serving	*A*	Full strength of cable, pounds
3/32	7	14	1¼	1	½	800
⅛	7	19	1½	1	½	2,000
5/32	7	19	1¾	1¼	½	2,800
3/16	7	19	1⅞	1¼	¾	4,200
7/32	7	19	2⅝	1¼	¾	5,600

NOTE.—Solder full length of splice without drawing temper of wire.

Rod End Pins.—The general appearance of the rod end pins as well as the dimensions suggested are shown in Fig. 51.

Bolts and Nuts.—Fig. 52 shows a type of bolt recommended for general airplane work but not for engine work. These have ball heads and the table gives general dimensions. These are of 3½ per cent. nickel steel. Fig. 53 gives similar dimensions for a plain head bolt while Fig 54 shows both plain and castle nuts with a ball on the under side. Fig 55 shows a plain bottom castle nut and gives its dimensions.

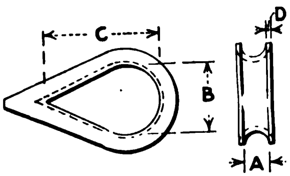


FIG. 47.—Thimble for wire ends.

Size of cable		Thickness of thimble *A*	Width of eye *B*	Length of eye *C*	Thickness of Metal *D*
1/16	0.062	0.09	0.35	0.70	0.032
3/32	0.094	0.09	0.35	0.70	0.032
1/8	0.125	0.13	0.35	0.70	0.032
5/32	0.156	0.17	0.40	0.80	0.032
3/16	0.187	0.21	0.50	1.00	0.032
7/32	0.219	0.24	0.60	1.20	0.032
1/4	0.250	0.25	0.70	1.40	0.032
9/32	0.281	0.30	0.80	1.60	0.032
5/16	0.312	0.33	0.90	1.80	0.040
3/8	0.375	0.39	1.00	2.00	0.040

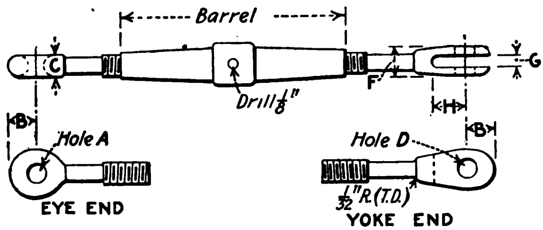


FIG. 48.—Turnbuckles.

No.	Strength in pounds	Eye ends, inches			Yoke ends, inches				
		A	B	C	D	B	F	G	H
1	500	5/32	9/32	1/8	3/16	9/32	3/16	5/64	3/8
2	1,000	5/32	9/32	1/8	3/16	9/32	3/16	5/64	3/8
3	1,500	3/16	11/32	3/16	3/16	11/32	1/4	5/64	3/8
4	2,000	13/64	11/32	3/16	3/16	11/32	5/16	7/64	7/16
5	2,500	19/64	13/32	7/32	1/4	13/32	11/32	7/64	7/16
6	3,000	19/64	13/32	7/32	1/4	13/32	11/32	7/64	1/2
7	3,500	19/64	7/16	1/4	1/4	7/16	7/16	13/64	1/2
8	4,000	19/64	7/16	1/4	9/32	7/16	7/16	13/16	9/16
9	4,500	21/64	7/16	9/32	9/32	7/16	1/2	13/64	9/16
10	5,000	21/64	15/32	9/32	9/32	15/32	9/16	17/64	9/16
11	6,000	23/64	15/32	5/16	5/16	15/32	9/16	17/64	9/16
12	7,000	23/64	15/32	5/16	5/16	15/32	5/8	17/64	5/8
13	8,000	25/64	1/2	11/32	5/16	1/2	5/8	21/64	11/16
14	9,000	25/64	1/2	11/32	3/8	1/2	11/16	21/64	11/16
15	10,000	29/64	9/16	3/8	3/8	9/16	11/16	21/64	11/16

Type of turnbuckle....................	Short	Long
Length of barrel........................	2 inches	4 inches
Made in numbers......................	1 to 7 incl.	1 to 15 incl.
Length between centers of eyes with:		
Threads flush with ends of barrel......	4 inches	8 inches
Ends extended a maximum............	4 3/16	8 3/16
Ends extended a minimum............	3 1/4	5 1/2

With two eye ends, thread one left-hand and the other right-hand.
With one eye end and one yoke end, thread eye end left-hand.

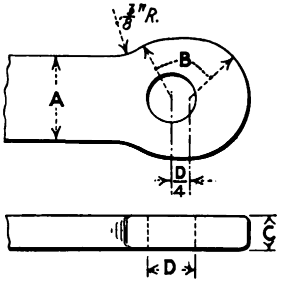


FIG. 49.—Clip ends.

CLIP ENDS

Turnbuckle		A	B	C	D
Number	Strength, pounds				
1	500	....	1/4	1/16	3/16
2	1,000	....	1/4	1/16	3/16
3	1,500	....	1/4	1/16	3/16
4	2,000	....	5/16	3/32	3/16
5	2,500	....	5/16	3/32	1/4
6	3,000	....	3/8	3/32	1/4
7	3,500	....	5/16	3/16	1/4
8	4,000	....	3/8	3/16	9/32
9	4,500	....	3/8	3/16	9/32
10	5,000	....	3/8	1/4	9/32
11	6,000	....	3/8	1/4	5/16
12	7,000	....	7/16	1/4	5/16
13	8,000	....	7/16	5/16	5/16
14	9,000	....	15/32	5/16	3/8
15	10,000	....	15/32	5/16	3/8

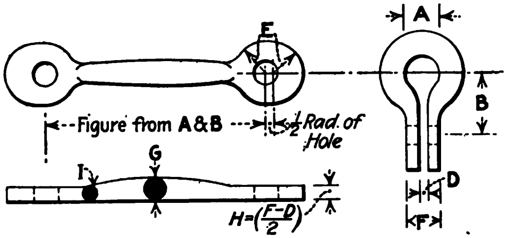


FIG. 50.—Shackles.

Turnbuckle		Width of clip lug *D*	Hole size *C*	Radius *E*	Diameter *A*	Length *B*	Diameter *G*	Diameter *I*	Diameter *F*
Number	Strength, pounds								
1	500	5/64	3/16	1/4	1/4	9/16	3/16	5/32	3/16
2	1,000	5/64	3/16	1/4	1/4	9/16	3/16	5/32	3/16
3	1,500	5/64	3/16	1/4	1/4	9/16	3/16	5/32	1/4
4	2,000	7/64	3/16	1/4	1/4	9/16	3/16	5/32	5/16
5	2,500	7/64	1/4	5/16	5/16	5/8	1/4	3/16	11/32
6	3,000	7/64	1/4	5/16	5/16	5/8	1/4	3/16	11/32
7	3,500	13/64	1/4	5/16	5/16	5/8	1/4	3/16	7/16
8	4,000	13/64	9/32	11/32	3/8	11/16	3/8	9/32	7/16
9	4,500	13/64	9/32	11/32	3/8	11/16	3/8	9/32	1/2
10	5,000	17/64	9/32	11/32	3/8	11/16	3/8	9/32	9/16
11	6,000	17/64	5/16	3/8	7/16	3/4	7/16	5/16	9/16
12	7,000	17/64	5/16	3/8	7/16	3/4	7/16	5/16	5/8
13	8,000	21/64	5/16	3/8	7/16	3/4	7/16	5/16	5/8

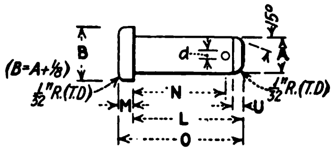


FIG. 51.—Rod end pin.

d = edges chamfered not to exceed 0.01 inch. T.D. = tooling dimension.

Size *A*	1/8	5/32*	3/16	7/32*	1/4	9/32	5/16	3/8	7/16*	1/2*
Limits	−0.002	−0.002	−0.002	−0.002	−0.002	−0.002	−0.002	−0.002	−0.002	−0.004
A	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.007
B......	1/4	9/32	5/16	11/32	3/8	13/32	7/16	1/2	9/16	5/8
M.....	3/64	3/64	3/64	3/64	1/16	1/16	1/16	1/16	3/32	3/32
L-N....	3/32	3/32	3/32	3/32	7/64	7/64	9/64	9/64	9/64	9/64
U......	3/64	3/64	3/64	3/64	1/16	1/16	1/16	5/64	5/64	5/64
d......	50	50	48	48	48	48	36	36	36	36
Cotter .	1/16	1/16	1/16	1/16	1/16	1/16	3/32	3/32	3/32	3/32
Length *L*										

* Future sizes.

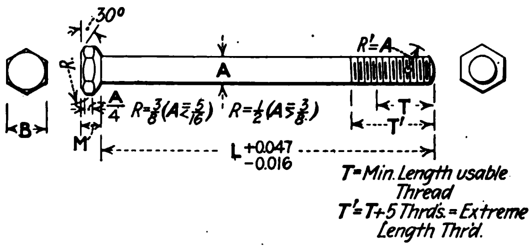


FIG. 52.—Recommended bolt.

All threads U. S. F. *R* = 3/8, [*A* = > 5/16] *R* = 1/2, [*A* = > 3/8]

Size—*A*...............	No. 8*	No. 10*	No. 12*	1/4*	5/16	3/8	7/16	1/2*	9/16*	5/8*
Threads per inch.......	32	32	32	28	24	24	20	20	18	18
Limits—*A*............	0.160	0.186	0.212	0.246	0.308	0.371	0.433	0.496		
	0.164	0.190	0.216	0.250	0.312	0.375	0.437	0.500		
Head diameter.—*B*.....	5/16	3/8	3/8	7/16	1/2	9/16	11/16	3/4		
Head height.—*M*......	11/64	11/64	11/64	13/64	1/4	5/16	23/64	3/8		

* Future sizes.

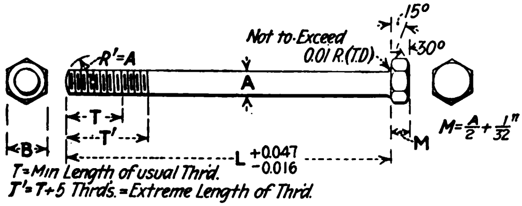


FIG. 53.—Plain head bolt.

All threads U. S. F. $M = \frac{A}{2} + \frac{1}{32}$ T.D. = tooling dimensions.

Size—*A*	No. 8	No. 10	No. 12	¼	5/16	⅜	7/16	½
Threads per inch	32	32	32	28	24	24	20	20
Limits—*A*	0.160	0.186	0.212	0.246	0.308	0.371	0.433	0.496
	0.164	0.190	0.216	0.250	0.312	0.375	0.437	0.500
Head diameter—*B*	5/16	⅜	⅜	7/16	½	9/16	11/16	¾
Head height—*M*	7/64	⅛	9/64	5/32	3/16	7/32	¼	9/32

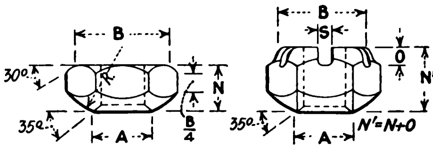


FIG. 54.—Ball seat nuts.

All threads U. S. F. N′ = $N + O$.

A	*B*	*N*	*R*	*A*	*B*	*N′*	*S*	*O*
No. 8	⅜	11/64	⅜	No. 8	⅜	¼	5/64	5/64
No. 10	⅜	11/64	⅜	No. 10	⅜	¼	5/64	5/64
No. 12	7/16	11/64	⅜	No. 12	7/16	17/64	5/64	3/32
¼	7/16	13/64	⅜	¼	7/16	19/64	5/64	3/32
5/16	½	¼	⅜	5/16	½	11/32	5/64	3/32
⅜	9/16	5/16	½	⅜	9/16	7/16	⅛	⅛
7/16	11/16	23/64	½	7/16	11/16	31/64	⅛	⅛
½	¾	⅜	½	½	¾	9/16	⅛	3/16

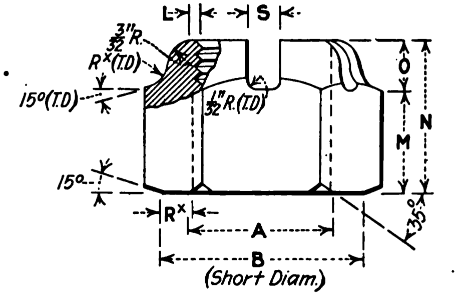


FIG. 55.—Plain castle nut.

All threads U. S. F. *O* = Also depth of slot. *T.D.* = tooling dimension.

A	*B*	*N*	*S*	*O*	*M*	*L*	*R*
No. 8 32	3/8	15/64	5/64	5/64	5/32	1/64	3/32
No. 10 32	3/8	1/4	5/64	5/64	11/64	1/64	3/32
No. 12 32	7/16	17/64	5/64	3/32	11/64	1/32	1/32
1/4 28	7/16	9/32	5/64	3/32	3/16	1/32	3/32
5/16 24	1/2	21/64	5/64	3/32	15/64	1/32	3/32
3/8 24	9/16	13/32	1/8	1/8	9/32	1/32	3/32
7/16 20	11/16	29/64	1/8	1/8	21/64	3/64	1/8
1/2 20	3/4	9/16	1/8	3/16	3/8	3/64	1/8

Magneto Base.—In order to facilitate the interchange of magnetos of different makes the dimensions shown in Fig. 56 are recommended for all magneto bases.

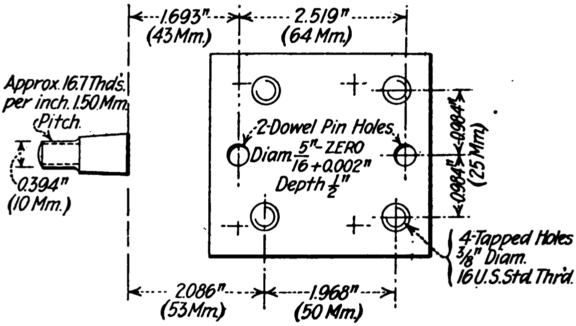


FIG. 56.—Magneto base.

Pipe-line Markings.—It is proposed to mark fuel pipe lines with red bands, lubrication pipe lines with white bands and air lines with blue bands for easily tracing all connections. These bands are recommended to be ½ inch wide and not over 24 inches apart.

Engine Supports.—The following dimensions (in inches) are recommended for standard engine supports:

Distance between timbers	12	14	16
Width of bed timbers	2	2¼	2½
Distance between centers of bolts	14	16¼	18½

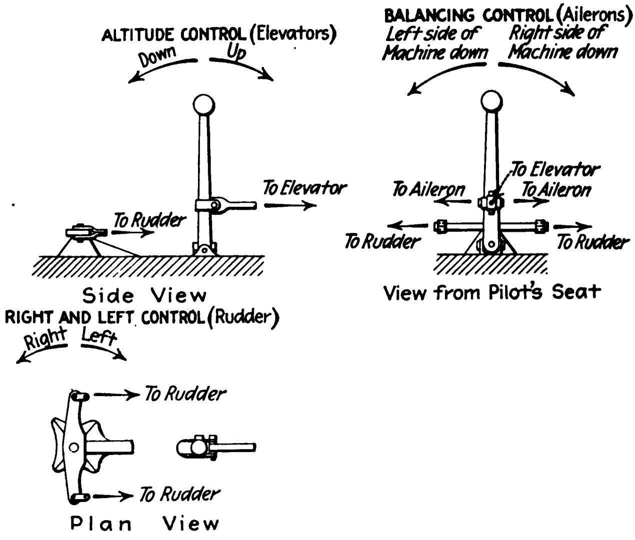


FIG. 57.—Standard stick control.

Spark-plug Dimensions.—The following dimensions for spark-plugs are recommended:

Thread: 18 millimeter, 1½-millimeter pitch.

Form of thread: international standard (same as U. S. standard only with one-half as much truncation at root of thread).

Gasket shoulder to end of shell: ⅝ inch.

Stick Control.—The illustration in Fig 57 shows the stick type of control in outline. No proportions are given but the general idea is clearly shown. This is used mostly on the small, fast airplanes.

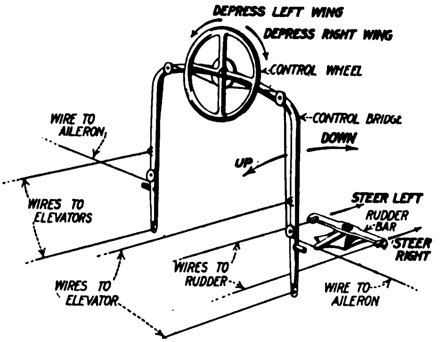


Fig. 58.—"Dep." control.

Wheel or Column Control.—This is shown in Fig. 58 and is sometimes known as the "Dep" (Deperdussin) of column control. This is more suitable for large, heavy machines with large aileron surfaces to be moved.

SECTION VI

WOODS FOR AIRPLANE CONSTRUCTION

The majority of the wood used in airplane construction is spruce and in order to secure suitable and uniform material, specifications have been drawn up as a guide in accepting material offered.

The specifications which have been proposed by the spruce men and which received the informal approval of the Government's representatives present are as follows:

Thickness.—Two to 6 inches, inclusive. At least 60 per cent. to be 3 inches and 4 inches thick. Not more than 40 per cent. 2 inches, 5 inches, and 6 inches thick.

Width.—All to be 4 inches and wider; not over 10 per cent. under 5 inches wide.

Length.—Fifty per cent. to be 18 feet and longer. Fifty per cent. to be 4 feet and longer.

Measurement.—Width and thickness fractional. Lengths in multiples of 1 foot.

Grain.—All lumber 3 inches and thicker shall be not less than 70 per cent. vertical grain of an angle of 45 to 90 degrees on each carload. All lumber 2 inches thick shall be not less than 30 per cent. vertical grain of an angle of 45 to 90 degrees on each carload.

Grades.—The grades agreed to are as follows:

GRADES AGREED UPON

The 50 per cent. of all lumber 18 feet and longer shall be clear four sides, straight grained, not less than six annular growth rings for each 1 inch, sound and well manufactured, free from shakes, spiral and curly grain.

This grade will admit of bright sap, wane, pinworm holes, slight variations in sawing, or other defects that will not impair its use for wing beams.

The 50 per cent. of all lumber 4 feet and longer shall yield clear cuttings, straight grained, not less than six annular growth rings per each 1 inch, sound and well manufactured, free from shake, spiral, and curly grain; some may contain knots, pitch pockets, wane, pinworm holes, slight variations in sawing, and other defects that will not impair its use for the purpose intended, providing, however, that each piece must produce, for buyer, clear straight grain, cuttings from 4-foot to 17-foot lengths, which shall not include over 5 per cent. of such cuttings 4 feet to 7 feet, inclusive.

The requirement regarding the number of rings per inch is the one most likely to cause trouble as the number of rings depends on whether the tree grew in good soil or poor to some extent and there is plenty of perfectly good spruce with from two to four rings per inch. This particular requirement will doubtless have to be modified according to the judgment of the inspector in order to obtain sufficient material.

SECTION VII

THE AIRPLANE ENGINE

While there is no intention to go into the design of engines to any great extent, it is well to have a general idea as to how the problem differs from that of the automobile engine. The two main differences are that the engine must be capable of running at its maximum power for long periods and that the weight shall be as light as possible, this varying from less than 2 to 5 pounds per horsepower. As the average automobile engine usually runs at from 15 to 25 per cent. of its maximum power, the difference can easily be imagined. A third added difficulty is the loss of power due to high altitudes, which will be considered later and some definite data given in regard to this point.

Ignition and spark-plug troubles are also more frequent on the airplane engine owing to this constant demand for high power, and these points may well be carefully studied.

There is a constant tendency toward higher engine speeds so as to increase the horsepower per pound of weight, this necessitating the gearing down of the propeller, which does not, however, seem to be considered as any special objection. According to present practice from 1250 to 1400 seems to be the best speed for the propeller, and many engines are designed for that speed so as to drive direct. A number, however, are now being run at as high as 2100 and there are predictions from French aviation engineers that 2500 will probably be attained in the near future. This high speed involves careful consideration of metals to be used and such details as valve openings and manifold areas. The increased speed may reduce the weight per horsepower even lower.

At the present time many engines are made with cylinders of steel either from tubing or from forgings and bored from the solid as in the case of the Gnome. Some use aluminum cylinders and line them with a steel sleeve, also bored from a solid forging. Cast iron, however, makes such a fine bearing metal for cylinders, especially at high speeds, that some engineers look for its return to favor in the new engines, probably in the shape of liners for aluminum cylinder castings. The question of piston material is also under dispute, aluminum being very largely used but cast iron of high grade still holding its own even in some of the lightest engines. Just as a basis for study and comparisons it is necessary to remember that in the airplane engine, even at its present slow speed of 1400, a cylinder approximately 5 by 7 inches must deliver about 30 horsepower.

The experiences of the British and French fliers, as voiced by Wing Commander I. W. Seddon, of the British Flying Corps, and Captain Lagrange of the French Air Service, are very interesting and of great value.

The great air problem seems to be to get an overwhelming number of fast, single-seater, fighting machines so as to clear the air of enemy fighters. This not only enables you to take your own observations in safety, but to keep enemy observers away from your lines, to prevent bombers from attacking, and at the same time to allow your bombing machines to attack at will. This, however, is not considered to be an efficient mode of fighting, unless you can send huge squadrons of bombing machines that can completely wipe out a fortification or destroy bases or troops massed for attack. The present practice in the fast fighting machine is to have 1 horsepower for every 10 or 12 pounds weight of machine, with the tendency to increase the power so as to give a horsepower for 8 pounds of machine. This means from 130 to 150 horsepower for a small fighting machine.

The French engine tests for a motor of new design consist of a 50-hour run, divided over 5 days. There is a 5-hour run in the morning and a similar run in the afternoon. The first half-hour of each run is at full load and the remainder at 90 per cent. load, as this is all a motor delivers at 6000 feet altitude, the power decreasing as the machine ascends. New motors of accepted design are run for 3 hours, pulled down and examined, reassembled and run 20 minutes. They are then ready for service.

EFFECT OF ALTITUDES

The difference in temperature at different altitudes is a problem peculiar to the airplane motor. The low temperature of a high altitude cools the motor excessively at times, and this is particularly bad when diving from above to catch an enemy beneath. As the motor is shut off to dive, the water cools still more, in spite of the decreasing altitude; and when you throw on power again at the new fighting level, you have a comparatively cold motor that is not lively and will not develop the power you would like at that particular moment.

Some of the problems involved in the development of engines of this type are summed up by Prof. Charles E. Lucke as follows:

The Problem of Airplane-engine Design

The problem of the airplane engine appeals strongly to every engineer because it is a problem of the lightest power plant. The lightest weight of engine proper per horsepower is to be secured first by obtaining maximum mean effective pressure at maximum speed: in other words, the product of the mean effective pressure and the speed must be a maximum. At the same time the weight of metal per cylinder, or per cubic inch of cylinder displacement per working stroke must be a minimum—and with both of these factors the engine must be reliable in operation. So far, this reliability factor has been weakest, though lightness has been secured in engines good for short periods of running.

Not only must the metal weight of engine per horsepower be a minimum, but in addition the fuel weight to be carried must also be a minimum because, as can readily be seen, the fuel weight necessary for flights of any length predominates over the engine weight. For example: taking ½ pound of fuel and oil per hour per horsepower as a fair value, it is readily seen how quickly that will catch up on engine weight when the latter is 4 or 5 pounds per horsepower.

In undertaking an analysis of the airplane-engine problem from the records, the only conclusion that can be drawn is along the line of type. Data are almost entirely lacking. On the question of general engine types, attention might be called to a few points:

The air-cooled motor has entirely failed in comparison with the water-cooled motor—the reasons are perfectly sound and secure. The two-cycle engine has given way to the four-cycle type.

Fixed cylinders have prevailed over rotating cylinders. Odd cylinder arrangements of queer, freaky forms have all been relegated to the scrap heap in favor of a few modern arrangements. The standard cylinder arrangements of today, which are the survivors of what may be called the inventive period, or at least the first inventive period, are the six and eight cylinders in line and the eight, twelve and sixteen V's.

It really appears therefore that the one valuable result of all our experience has been the selection of a few typical arrangements which we are now compelled to study, as minutely as circumstances permit, for the purpose of standardizing and mechanically perfecting these particular types as standard machines which will run as reliably as our stationary engines and which can be manufactured as economically.

Taking up each of the factors of airplane-engine design that seem important, in as specific a way as seems proper, the first one I wish to consider is the value of efficiency and the relation of efficiency to minimum weight.

Plotting hours of running as abscissæ against weight of engine, with fuel and oil, as ordinates, for the air-cooled and the water-cooled types of motor, respectively, so that the intercept on the vertical axis represents the weight of engine metal alone, and the ordinates away from the axis represent the weight of metal plus fuel and oil, one finds that the two curves cross at some period of running beyond which, therefore, the water-cooled heavier engine, because of its lower fuel consumption, becomes lighter in comparison.

Weight of Air and Water-cooled Engines

The metal weight of the water-cooled motor is about one and one-half times that of the air-cooled motor, and the slope of the combined-weight line of the latter compared with that of the former is as two is to one—that is to say: the consumption of the air-cooled motor is approximately twice that of the water-cooled motor. These facts are responsible for the crossing of the lines.

Of the conditions for efficiency which bear upon this question of fuel weight, and which have led to the selection of the water-cooled motor as a type, the first is the compression. The higher the compression the higher the efficiency, and there is no limit until preignition occurs. Statements will be found in textbooks to the effect that there is a limit, but they are the results of mistakes in interpretation, and are erroneous. The amount of compression possible is limited, however, by the metal temperature and by the temperature of the mixture as admitted. Naturally the warmer the mixture during suction, the sooner it reaches ignition temperature by compression. Therefore, suction heating is a limit. Again, the interior metal temperature, if it is high (as it is always), may cause trouble by contact with the mixture during compression, and some portion of the mixture may be brought to its ignition temperature by hot-wall contact long before the main mass is brought to this ignition temperature by compression alone. It requires only one such hot spot to wreck a well-laid plan.

The next factor in efficiency is the mixture quality, and in this there are the following controlling elements: first, mixture proportions. Any excess fuel means direct waste, but it also means carbonization and fouling. Excess air quickly makes the mixture practically non-burnable. Therefore, mixture proportions must be accurately controlled—more accurately than is possible with any existing carbureter. Carbureters are not yet satisfactory, and as soon as satisfactory carbureters are secured from the standpoint of proportionality of the mixture, we may expect to see a further reduction in fuel consumption and more reliable operation.

Dryness of mixture is a matter of coördinate importance with mixture proportions. When mixtures are wet, that is not completely vaporized, the air and fuel cannot be uniformly distributed to the various cylinders by the manifold system. One cylinder will get a different charge from another, as can be easily proved by pressure gages. There are rarely two cylinders alike as to maximum pressures on a multicylinder engine using wet mixtures. Drying of the mixture will cure that fault, and also cure the carbonization that comes from the vaporization of the liquid in the presence of the burning gas when it has been admitted to the cylinder in a liquid state.

The third factor of the mixture question is homogeneity. However accurately the mixture may be adjusted as to fuel and air ratio, however carefully the mixture may be distributed, cylinder to cylinder, the fact remains that, in order to produce economical results, the charge in any one cylinder must be uniform in every cubic inch of it. It is not sufficient that the right amount of air be in the cylinder even if the fuel is vaporized when the latter is all in one corner.

Following mixture quality, the next factor in efficiency is rate of flame propagation with reference to piston speed. It can be shown that the explosion line of the indicator card following compression must be maintained vertical for maximum efficiency. Now, the rate of propagation is the one factor that tends to hold it vertical. If the propagation rate is high enough for a given piston speed, so that the explosion line is vertical, the efficiency will be high. But should the piston speed exceed a certain value, then the explosion line will begin to lean toward the expansion line, until by and by it becomes horizontal and merges into the expansion line, with a consequent large loss of work area and low efficiency or high fuel consumption. Therefore, there is for every given mixture a limiting piston speed that cannot be exceeded without destroying efficiency, and we are now approaching that speed in airplane engines.

Pressure and Speed

The next related factors are mean effective pressure, and speed. These are the prime factor for the output of a cylinder.

If the mean effective pressure were constant, then horsepower with reference to speed would follow a straight line. The mean effective pressure is not constant as the speed varies, however. Therefore, plotting horsepower against speed gives a curve having the general form of concave downward and consisting of several separate portions, each worthy of study. There is usually a straight portion over a given speed range, during which the mean effective pressure is constant. For lower speeds the mean effective pressure is lower, and for higher speeds the mean effective pressure is again lower. From the point where, with increasing speed, the straight line becomes a concave-downward curve, the mean effective pressure is decreasing as speed increases, until at the point where the tangent to the curve becomes horizontal, the rate of increase of speed is exactly equal to the rate of decrease of mean effective pressure. At a little higher speed mean effective pressure decreases faster than speed increases, and finally the curve drops down toward zero power.

So much for the facts. An analytical engineer cannot be content with those facts, however, but finds it necessary if he is to apply a cure to go behind the facts to ascertain the reasons. The first step in doing that is to determine the volumetric efficiency of the engine by measuring the air and fuel, and comparing the total volume of mixture taken in, with the piston displacement. If the volumetric efficiency be plotted against the speed, much light is thrown on the situation. In the first place, the volumetric efficiency falls off in the region of very low speed, where the mean effective pressure is low; it is constant over the region of constant mean effective pressure, where the horsepower speed line is straight, and then at some high speed it again decreases. It is clear, therefore, that curvature of the horsepower-speed line is due to a corresponding variation of volumetric efficiency. It may be found, however, that at some high speed the horsepower-speed line falls before the volumetric efficiency. This calls attention to the fact that the falling off of mean effective pressure at high speeds may not be due primarily to volumetric efficiency but to other causes, and recognition of this starts a search for those causes.

The first of these causes is too slow a combustion, or too high a piston speed. That is to be corrected by adding an additional ignition source, or by moving the spark plug from a side wall to a center point. Igniting at more than one point or at a more central point will cure this defect, and again cause the dropping points of both horsepower-speed and volumetric efficiency-speed curves to lie on the same speed line.

Again, it will be found that a change in the valve setting changes this mean-effective-pressure curve at both ends, but every change in the valve setting also changes the mean effective pressure, and the volumetric efficiency is itself the direct measure of whether or not one has the best valve setting.

Now, it is curious that most people have played with cams and adjusted them back and forward by guesses, and have never bothered about the air meter, which is the only positive means of arriving at best cam forms and valve timing for sustained mean effective pressure at high speeds.

Many more analyses along the above lines could be given, but enough has been said to call attention to this most important means of studying the problem of maximum power at high speed, not only revealing what is the matter but pointing out clearly the direction in which to correct the fault.

So much for efficiency and mean effective pressure, or efficiency and horsepower per cubic foot of cylinder. Those two factors bear directly on the fuel weight to be carried and the output per cubic foot of cylinder. What will be the weight of that cubic foot of cylinder? This has to be judged both by qualitative and quantitative analysis. It is impossible to give any quantitative analysis without long mathematical treatment, so I will undertake only the qualitative analysis.

The first point in qualitatively analyzing unit metal weight of the multicylinder engine is to recognize that the engine can be divided laterally by planes into sections of one cylinder each. The end sections are the same as each other, but are different from the intermediate sections. Therefore, to study qualitatively the relative weights of two typical constructions, the mind must be concentrated upon these sections, each one of which includes a cylinder, a piece of frame, a piece of shaft and the other parts that go with the section.

Position of Cylinders

From this point of view, consider multiplication of cylinders in line *vs.* radially or circumferentially. It will appear that the weight of the cylinder, piston and connecting rod, is just the same no matter how the cylinders are arranged, but the frame weight and shaft weight are reduced by any multiplication. It is clear also that, other things being equal, the lighter arrangement is circumferential rather than longitudinal multiplication.

Now, going back to the history of the situation, we find every conceivable combination has been tried, but these have finally crystallized to not more than two kinds, giving the V-type engine and the engine with cylinders in line.

Considering the effect of cylinder diameter upon unit metal weight, it will appear that from the unit weight standpoint the cylinder diameter should be as large as possible, because the wall thickness of a cylinder is always greater than necessary for the stress for other structural reasons. A $\frac{1}{16}$-inch cylinder of steel will not be stressed over, say, 10,000 pounds per square inch. The cylinder could be made much thinner than this and still have a good working stress if there were not other structural objections to it. This being the case, the larger the cylinder for a cubic foot of displacement the less the unit metal weight in the wall, and the only limit to large diameter is good running.

Considering the stroke, as this is increased the metal in the cylinder piles up endwise, or axially, too fast with reference to volume, and therefore for minimum unit metal weight, the shorter the stroke the better. In proportion, we are using, normally, shorter strokes in aeronautical motors than in automobile engines for that reason.

Again, as affecting the metal weight, we have the connecting rod length. Clearly, the shorter the connecting rod the shorter the frame, and therefore the more metal saved. The only objection to the shorter connecting rod is an excessive angularity, which introduces stresses requiring metal thickening in other places.

The number of cylinders should be as large as possible up to the point where the weight of the connecting parts has to be increased. A two-cylinder engine has less than twice the weight per cubic foot of displacement than a single-cylinder, for the reason that the number of end supports for the shaft, etc., is not increased. Similarly a three-cylinder has less than three times, a four-cylinder less than four times, and so on; and the weight per cubic foot of displacement gets less and less until a certain number of cylinders—somewhere about six—is reached where the shaft diameter and the weight of the frame must be increased so as to retain the necessary stiffness, whereupon the saving in weight by multiplication is neutralized. This appears to be about the limit of saving by line multiplication.

The metal weight per cubic foot of cylinder displacement has to be taken up along the lines indicated, extending the study to the form *vs.* weight of each individual member. It will appear, as one examines the forms of these individual members, that one form is clearly susceptible of less weight than another—even with the same working stresses or with equal factors of safety.

The first of these studies should be undertaken with reference to cylinders. The first cylinders built were made of cast iron, with head, cylinder and jacket cast in one piece, and the valves being arranged in a side pocket—the ordinary T- or L-head construction. It is clear that the weight of the valve pocket is detrimental. The first step in any cylinder-weight reduction, then, is to take that pocket away, retaining the cast cylinder (on the assumption that we do not know how to make any other kind) and putting the valve in the head. This results in the valve-in-head construction, which is now practically universal, but which, strange to say, it took 6 or 7 years to realize.

A similar instance of slow realization of facts exists with reference to the cast-iron jacket wall, which has no other function than to hold water. Cast iron for that purpose, especially in an airplane engine, is wasteful of material, so the next step is to get rid of the cast iron. When one stops to think how it is to be done, a structural difficulty becomes apparent, and therefore one must not too readily condemn the holding on to the cast-iron jacket. The difficulty is of course the necessity of providing openings for the intake or outlet from each valve, an igniter plug hole and at least two pipe connections for the jacket, and in an aeronautical engine under heavy stress there is some driving gear which requires fastenings. This naturally tends toward the use of a casting.

Suppose such a casting is used, with inlet and one exhaust valve each with a port leading out, and such valve seating in the head which turns down to form the cylinder; then the casting may be led around the top, forming the enclosure of the head jacket and joining the several outlets and coming down outside the cylinder. The cylinder-head jacket casting ends in the form of a skirt at about the level of the valve deck, and to this end a tube jacket can be added by any one of several possible fastenings. That is the next step: cast iron for the cylinders, head and head jacket in a one-piece casting, but with sheet metal for the jacket over the cylindrical barrel. It is a logical step, but it took several years to reach it just the same.

Reducing the Weight

Proceeding along the same line of weight reduction, the next step is to cut away this cast iron joining the ends of the ports and forming the wall of the head jacket, and substitute sheet metal welded to the ports by the oxygen welding system. Wherever there are connections to be made for attachment of gears, there must be some additional supports welded or brazed on. The cast-iron cylinder is still there, and with cast-iron ports.

There is a fundamental objection to a cast-iron cylinder for aeronautical work, and it is a perfectly valid one. Cast-iron cylinders do not have to be very thick to be amply strong, so far as the gas-pressure stresses are concerned, but the fact remains that so long as they are cast iron, no one knows whether they are good cast iron inside or not, and the cast iron cut down to 1/8 inch in thickness incurs taking some chances. Hence attention is turned toward steel.

Drawn steel or forged steel is a reliable material and a logical selection, so designers have sought means of using it; but when one stops to think how to use a drawn-steel tube for a cylinder, and get the necessary attachments on it, one soon recognizes that the matter is not so easy as it looks. That is the reason the adoption of the steel cylinder was so long delayed.

There are now several schemes developed for steel cylinders. The first of these is a steel cylinder of a drawn tube formed without a head, screwed into a separate head carrying the ports and the head jacket cast in one piece. This is rather a satisfactory way of attaching a head, but it involves more than one difficulty. When such a screwed head is set up against the shoulder, it is not at all clear just where it is going to stop; and to secure the proper position one must either scrape the faces or shim them—neither of which is a nice job. A further objection is the considerable weight of the cast iron in a rather complicated casting, and also the inner wall of that cast iron is a stress wall, the stress of which must pass through the thread to the cylinder. There is no objection to using a casting if it is not stressed, but a casting under stress is not satisfactory and is to be retained only in the absence of something better.

Complete elimination of castings has been tried by using all steel and sheet metal welded together, but this did not prove satisfactory for a very interesting reason. A flat sheet-metal head on which the valves are seated will not remain flat, and a round valve seat will not stay round. Such sheet metal tends to warp out of shape, and with it the valves will not stay tight. However, the material does not break, which is something worthy of thought.

To eliminate the weld between the steel cylinder and head, another construction was developed. In this, a seamless drawn-steel shell with head just like a cartridge is used, and two holes are arranged in the head to seat the valves. It is evident that this is a structure which is sound against all kinds of stresses. It still has some of the difficulties of warping the seats, causing leakage of the valves; and when a valve leaks the amount of heat developed is tremendous. Once a valve starts to leak, it is only a question of a short time before it will be completely destroyed.

The particular construction of cylinder just described is rather difficult to attach to its jacket ports. It is interesting to note one case at least in which a satisfactory attachment has been worked out, and that is the Hispano-Suiza engine, now used on the European war front, and now also being built in this country. In this particular engine the entire outside of the cylinder is threaded, and the cylinders are screwed into an aluminum casting which is double-walled just like the cast-iron block casting of an automobile engine. The thread performs the double purpose of holding the cylinder in place and bringing its head up against the aluminum cast head which carries the ports, and also acting as a thermal bridge between the metal of the cylinder and the metal of the aluminum casting which carries the jacket water. Without the latter there would be poor thermal contact and overheating of the cylinder. While this construction is not entirely satisfactory, it is nevertheless very interesting and suggestive. It immediately calls attention to the fact that a water jacket may be made of an aluminum casting and the ports formed just as easily as in iron, the steel interior carrying the stress due to the interior gas pressures.

It is, however, quite feasible to get rid of the double aluminum wall down along the cylinder barrel into which this steel cylinder is placed and which carries the ports above, by leaving out its interior wall and retaining the outside, or even by stopping the wall just below the head as a skirt to take a short thin tube which may itself be of aluminum, ending at the bottom in a cast stuffing-box ring to act as a joint against the steel cylinder. That, so far as I know, represents the last word in this direction, the steel cylinder head being bolted up to the aluminum head-port casting at the valve seat bases, and not just pressed up against it by a remote thread.

The All-steel Cylinder

Finally, there is to be noted the one-piece steel-forging construction for cylinder, cylinder head, ports and ignition holes, surrounded by a sheet-metal welded jacket, a very satisfactory though expensive construction.

These heads are themselves a subject of considerable study. We have first a plain head in which the valve inside diameter is half the cylinder less the width of seat, and half the bridge between the valves. Both valves have stems pointing upward and parallel. The plain cylinder, then, which can be made of a plain seamless-drawn steel cartridge, and which is so desirable structurally, limits valve diameter, and this is a factor against it. Valve diameter is a strong influence in volumetric efficiency and weight of charge, controlling, as it does, flow-resistance conditions. Naturally, designers must get the volumetric efficiency as high as possible by keeping flow resistance as low as possible. Therefore, the tendency is to go toward larger valves than is possible with the previous arrangement.

One variation in form for this purpose is the flat bulged head where the valve diameter is larger than before by the amount of the bulge. The flat bulged head is a very desirable thing for larger volumetric efficiency and higher mean effective pressure, but offers some difficulty in manufacture when one is making a one-piece seamless drawn-steel job, but not a serious difficulty.

Another suggestion for getting the same result is to bulge this head upward in the form of two flats and put the valves on the two inclines. It is perfectly clear that a very large increase in diameter can be secured in this way. The valve stems in this case are not parallel but diverge at any angle and the limit is reached when the angle is 180 degrees, in which case they are horizontal.

The question of block arrangement of cylinders and their jackets *vs.* separate units, deserves some attention. In some cases each cylinder with its jacket and head is entirely separate. In other cases the jackets are cast or welded in a block form, around more than one cylinder—sometimes two and sometimes four, and in some cases six. It is clear that the more cylinders included in the jacket block, the less will be the weight of the jacket, because the length of the tangent to two jacket circles is less than a half circumference. But there are objections to the block, and in some cases it may not pay to use it.

In a case in point, a cast-aluminum block jacket was set down over four steel cylinders which were bolted to the frame by their usual flanges and studs. These cylinders gave trouble on the outer flanges, the end studs breaking off or pulling out. The trouble was caused by the crank-case running hot, expanding; and the aluminum-block cylinder casting running cool, because it was water-jacketed, not expanding. The cylinders being bent inward tore the stud ends right out.

Another point: the steel cylinder is naturally flexible, and it belongs—in fact the entire motor belongs—to that class of structures which should properly be termed flexible, exactly similar to bridge structures.

These flexible motors weave just as the engine of a steamship weaves. To attempt to hold one against springing is to attempt what is practically impossible. The cylinders of airplane engines should all be perfectly free to go as they will, and not be held on the top in any way. All the block arrangements of cylinders of the sort just described, are therefore objectionable.

Steel cylinders have a natural spring and give to them, and if let alone they will serve well, but attempting to secure them may result in serious distortions, or in highly localized excess stresses.

Proceeding in the same qualitatively analytical style, the complete paper takes up successively the problems of the piston, valves, valve gears, frame, etc., indicating how a gradual realization of conditions has led to modifications of design, and pointing out factors not even yet considered and making suggestions for meeting them. For instance, in connection with the valves the author makes a thermal study of the problem which, he says, has not been undertaken by anyone in the shops. He does the same for the piston, and the crankcase he analyzes from its consideration as a stress member.

The paper sums up with the pointed statement that the aeronautical engine is emerging from the stage of invention to the stage of design; as a light, high-tensioned steel structure, consisting of seamless tubing and forged or welded steel parts, possibly formed in drop-forge dies. Add to that steel stress structure certain members, such as the piston, exhaust valve and guide, designed primarily for heat-flow conditions and not for stresses. Add to that again certain closing members, such as the ports for the intake and exhaust, which can be very properly cast in aluminum; and the oil crankcase closure, which can be made of any desired materials.

EFFECT OF ALTITUDE ON THE HORSEPOWER OF A GASOLINE ENGINE

There are two sources of power loss in a motor operating at high altitudes. One is the direct loss in horsepower due to the lower quantity of fuel in a given volume and the second is an indirect loss due to the drop in compression. The horsepower loss due to the second cause will not be considered.

P_1 = compression at sea level.
P_2 = compression at desired level.
A_1 = atmospheric pressure at sea level.
A_2 = atmospheric pressure at desired level.
H_1 = horsepower at sea level.
H_2 = horsepower at desired level.

$$\frac{P_1}{P_2} = \frac{A_1}{A_2}$$
$$\frac{H_1}{H_2} = \frac{A_1}{A_2}$$
$$\frac{P_1}{P_2} = \frac{H_1}{H_2}$$

To maintain the sea-level compression at various altitudes above sea level the compression ratio must be increased by a factor which varies with the altitude.

F = factor.
V = total cylinder volume, including compression space.
V_1 = compression space.
$\frac{V}{V_1} = R$ = compression ratio.

$$P_1 = A_1\left(\frac{V}{V_1}\right)^n$$
$$P_1 = A_1 R^n$$
$$P_1 = A_2 (F R)^n$$
$$A_1 R^n = A_2 (F R)^n$$
$$(FR)^n = \frac{A_1 \ R^n}{A_2}$$

A_1 = atmospheric pressure at sea level.
A_2 = atmospheric pressure at desired level.
P_1 = compression pressure at sea level.
n = logarithmic exponent.

$$F R = R\sqrt[n]{\frac{A_1}{A_2}}$$
$$F = \sqrt[n]{\frac{A_1}{A_2}}$$

After the compression ratio has been increased according to diagram 4, Fig 58A, itwill be necessary to increase the displacement of the engine if it is desired to maintain the sea-level horsepower at various altitudes.

D_1 = displacement at sea level.
D_2 = displacement necessary to maintain power at desired level.
A_1 = atmospheric pressure at sea level.
A_2 = atmospheric pressure at desired level.
$\frac{D_2 - D_1}{D_1}$ = per cent. of D_1 which must be added to itself to give D.

$$\frac{D_2 - D_1}{D_1} = \frac{D_2}{D_1} - 1$$
$$A_1 D_1 = A_2 D_2.$$
$$\frac{D_2}{D_1} = \frac{A_1}{A_2}$$
$$\frac{D_2}{D_1} = \frac{A_1}{A_2} - 1$$

EFFECT OF ALTITUDE ON ENGINES

One of the points in which airplane engines differ from those used in any other service is the effect of altitude upon the performance of the engine. This affects the compression of the engine, and with it the power which can be delivered, and it also affects the cooling water in the radiator, as the boiling point of water

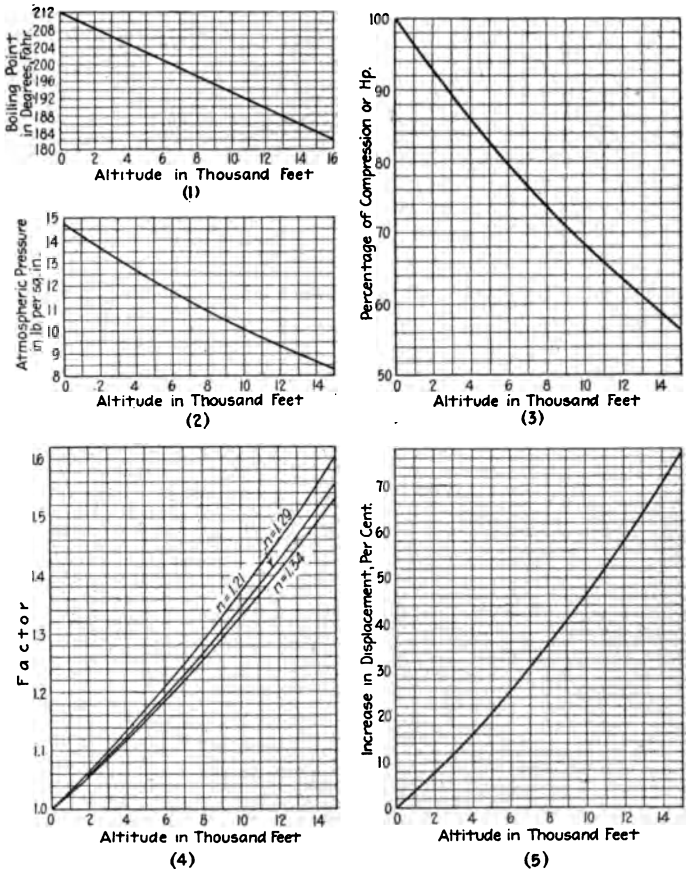


FIG. 58*a*.—Effect of altitude on engines.

drops gradually as the altitude increases. The two diagrams 1 and 2, Fig. 58*a*, show how the boiling point drops and also the way in which the atmospheric pressure gradually decreases.

The effect of altitude on the horsepower of the engine is shown in the three tables which follow. Diagram 3 shows the decrease of horsepower up to 15,000 feet, at which point it is seen to be a trifle over 56 per cent. of the horsepower developed at sea level. Diagram 4 shows how the compression ratio must be increased with the altitude in order to maintain the same horsepower as at sea level. This is given for three different factors, or different values for *n*. Thus for an elevation of 15,000 feet the factor must be increased 1.6 times.

But even if we increase the compression it will also be necessary to increase the displacement or cylinder capacity if we desire to maintain the same horsepower as at sea level. The amount of this displacement increased is shown in diagram 5, all of these tables being authorized by the S. A. E.

SECTION VIII

THE CURTISS ENGINE

There are so many Curtiss engines in use, both in training machines and in other service that the following suggestions, authorized by the Curtiss Aëroplane & Motor Corporation are likely to be found very useful. While these refer especially to their well-known OX or 90-horsepower engine, they will apply in many cases to the larger engines built by this company. These have 4 by 5-inch cylinders, normally run at 1400 r.p.m. and weigh 390 pounds complete. Other features are:

Specification of Curtiss Motor

Fuel consumption, normal per horsepower-hour	60 pounds
Oil consumption, normal per hour	2.70 pounds
Capacity of oil reservoir	925 cubic inches
Installation dimensions:	
Overall, length	56¾ inches
Overall, width	36 inches
Overall, depth	35¾ inches
Width at bed (inside supports)	11½ inches
Height from bed	17¾ inches
Depth from bed	12 13/16 inches
At carbureter	18 inches
Bed bolts (center to center)	12⅞ inches

Setting Up

Study carefully the dimensions shown in the installation diagram.

The bearers or beds should be 2 inches wide by 3 inches deep, preferably of laminated hardwood, and placed 11⅝ inches apart. They must be well braced.

The six arms of the base of the motor are drilled for 3/8-inch bolts, and none but this size should be used.

1. Anchoring the Engine.—Put the bolts in from the bottom, with a large washer under the head of each so the head cannot cut into the wood. On every bolt use a castellated nut and a cotter pin, or an ordinary nut and a lock-washer, so the bolt will not work loose. Always set motor in place and fasten before attaching any auxiliary apparatus, such as carbureter, etc.

2. Inspecting the Ignition-switch Wires.—The wires leading from the ignition switch must be properly connected—one end to the motor body for ground, and the other end to the post on the breaker box of the magneto (see the wiring diagram in this book).

3. Filling the Radiator.—Be sure that the water from the radiator fills the cylinder jackets. Pockets of air may remain in the cylinder jackets even though the radiator may appear full. Turn the engine over a few times by hand after filling the radiator, and then add more water if the radiator will take it. The air pockets, if allowed to remain, may cause overheating and develop serious trouble when the engine is running.

4. Filling the Oil Reservoir.—Oil is admitted into the crank case through the breather tube at the rear. It is well to strain all oil put into the crank case. In filling the oil reservoir be sure to turn the handle on the oil sight-gage till it is at right angles with the gage. The oil sight-gage is on the side of the lower half of the crank case. Put in about 3 gallons of the best obtainable oil, Mobile A recommended. It is important to remember that the very best oil is none too good.

5. Oiling Exposed Moving Parts.—Oil all rocker-arm bearings before each flight. A little oil should be applied where the push-rods pass through the stirrup straps.

6. Filling the Gasoline Tanks.—Be certain that all connections in the gasoline system are tight.

7. Turning On the Gasoline.—Open the cock leading from the gasoline tank to the carbureter.

8. Charging the Cylinders.—With the ignition switch OFF, prime the engine by squirting a little gasoline in each exhaust port and then turn the propeller backward two revolutions. Never open the exhaust valve by operating the rocker-arm by hand, as the push-rod is liable to come out of its socket in the cam follower and bend the rocker-arm when the engine turns over.

9. Starting the Engine by Hand.—Always retard the spark part way, to prevent backfiring, by pulling forward the wire attached to the breaker box. Failure to so retard the spark in starting may result in serious injury to the operator. Turn on the ignition switch with throttle partly open; give a quick, strong pull down and outward on the starting crank or propeller. As soon as the motor is started advance the spark by releasing the retard wire.

10. Oil Circulation.—Let the engine run at low speed for a few minutes in order to establish oil circulation in all bearings.

With all parts functioning properly, the throttle may be opened gradually for warming up before flight.

Valve Setting and Timing—Magneto Timing

When the motor leaves the factory its valves are properly set and timed. Scarcely any trouble is experienced with the valves of the Curtiss engine. Under normal conditions they are practically free from warping and pitting. An occasional grinding is necessary to bring them to a perfect seat and to

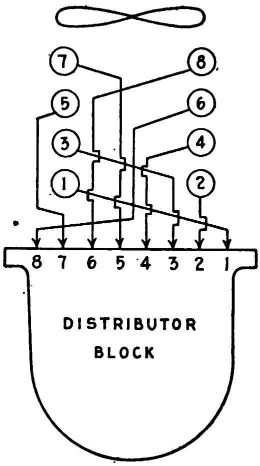


Fig. 59.—Distributor block.

clean off any collection of carbon. The inlet valves are of high-grade nickel steel; the exhaust valves are of tungsten steel.

1. Valve Setting.—After grinding and cleaning set the inlet valves at 0.010 clearance and the exhaust valves at 0.010 clearance. This setting should be done on each cylinder just after inlet valve has closed. If the stem is indented due to any cause, remove the valve and grind the stem end to a flat surface.

2. Valve Timing.—After setting the clearance turn the engine in the direction of rotation till the piston of No. 1 cylinder is 1/16 inch past top center. Then turn the camshaft in its direction of rotation till the exhaust valve on No. 1 cylinder has just closed. Put on the camshaft gear, being sure that the keyway of the gear lines up with the key in the camshaft.

Thus set and timed, the inlet valves will open 12 degrees past top center and close 40 degrees past bottom center; the exhaust valves will open 45 degrees before bottom center and close on top center.

3. Magneto Timing.—Turn the engine in the direction of rotation till the intake valve of No. 1 cylinder has closed; then turn the engine in the same direction till the piston of No. 1 cylinder is on top dead center; then turn the motor backward till the piston of No. 1 cylinder is 1/2 inch from top center. Turn the armature of the magneto in the direction of its rotation (it is the same as that of the crankshaft) till the distributor brush is on No. 1 segment with the breaker points just ready to open. Put on the magneto gear, using the same precaution as given for engaging the camshaft gear. This should bring the firing-time of all cylinders to 30 degrees before top center. The distributer diagram is shown in Fig. 59.

The spark advance lever should be in position of full advance during this whole operation. The gap between the breaker points should be 0.018 inch and that of the spark-plug points 0.023 inch.

IGNITION

The magneto used on the Curtiss engine is of the high-tension type.

The firing order and cylinder arrangement is as shown on the wiring diagram.

Ignition troubles are usually traced to faulty spark plugs. A common cause of spark-plug failure lies in the intensity of the spark itself, it eventually burning away the electrodes and thereby widening the gap, which at low speed causes missing. To test a spark plug connect it up with its terminal and lay it upon a cylinder of the motor for ground connection.

Turn the engine over briskly, under which conditions the spark plug should give a good spark.

All gasoline connections should be cut off before this test.

Trouble with the magneto itself is sometimes due to dirt and over-lubrication. If the magneto is suspected of being at fault unscrew one of the spark plugs, connect it up with its terminal, and lay it upon a cylinder of the motor for ground connection. Crank the engine vigorously. If no spark is seen it will be the wiser course to unscrew several plugs, and subject them to the same test before condemning the magneto or the wiring. Should no spark appear as the several plugs are tested, detach the switch wire from the magneto terminal on the interrupter housing-cover and test the plugs again. A spark under these conditions will indicate a short-circuit in either the switch or the switch cable. If there is no spark the interrupter should be inspected—care being taken to see that the platinum points are clean and smooth, and that the interrupter lever moves freely on its pivot. If the spark still fails remove the aluminum bonnet from the shaft-end of the magneto, thus exposing the safety spark gap. Turn the engine over rapidly. If a spark is seen in the safety spark gap the fault will be found not in the magneto but in the distributor, in the spark-plug cables, or in the spark plugs themselves. If no spark is visible in the safety spark gap the trouble is internal; the magneto must be returned to the manufacturer for repairs. Under no conditions should the magneto be taken apart beyond the removal of the interrupter, the distributor plate, and the bonnet from the shaft end. Nothing good can be accomplished by removing the end plates of the magneto, and permanent injury is almost sure to result.

The inside of the commutator should be kept clean and lubricated with high-grade cylinder oil—not in too large quantities, however. Graphite should never be used on the commutator.

Lift out the distributor plate occasionally, without disarranging the wiring, and remove any accumulation of oil, dirt, or moisture.

Lubrication

The proper lubrication of any mechanism is of so vital importance, and any neglect is so sure to cause expensive repairs that the mechanician should make it his unfailing habit to look after it daily. The Curtiss lubrication system is easily understood and requires little time for proper attention.

The system is force feed and spray.

The lower half of the crank case is used as the oil reservoir and carries a sight-gage that indicates at all times the quantity of oil it contains. The case is so designed that its center is always its lowest point and is consequently the point at which the oil always gathers. This is a highly important feature of Curtiss construction, as at no practical flying angle can the cylinders become flooded with oil. Inside the crank case are two baffle plates sloping from the ends toward the center and leaving at the bottom a ¾-inch opening their full width.

A simple gear pump forces the oil from the low point of the crank-case sump, through the hollow camshaft to all the camshaft bearings; thence through connecting tubes to the crankshaft bearings. From these bearings the oil passes through the holes drilled in the crankshaft into the hollow crankshaft and hollow crankshaft throws to the connecting-rod bearings.

The oil is thrown off the crankpin bearings in a spray, on to the piston-pin bosses, thence through holes in bosses to piston-pin bearings. Grooves in the pistons carry the oil up on to the cylinder wall.

The magneto gear and camshaft gear are lubricated by spray from a hole in the retaining screw of the camshaft gear. The thrust bearing is lubricated by spray from a hole in the rear of the crankshaft.

The oil pressure is regulated by a regulating valve in the line, which acts as a bypass allowing the surplus oil to flow into the oil sump.

All bearing pins for the rocker-arms and for the forked ends of the push-rods are hollow, but plugged at both ends. Minute holes are drilled in alignment with the external holes. As oil is forced into these external holes the hollow spaces inside the pins act as reservoirs, and will oil evenly all bearings of the rocker-arm mechanism for several hours after being filled.

Overhauling and Inspection

Every engine should have a complete inspection at the end of every 50 running hours. To do this properly, the engine must be dismantled. When new, the engine should not be run for more than 5 hours, without thoroughly draining off all oil, and carefully cleaning the strainer. This procedure should be repeated at the end of the second 5-hour period of operation, and then at the end of the next 10-hour period.

Any first-class engine mechanic can do this work, noting these few points carefully:

The crankshaft and crankpin bearings are made two to three-thousandths of an inch larger than the journal. The bearings should **never** be tighter than this and a trifle more clearance will do no damage. Scraping the bearings should be undertaken only when absolutely necessary as when relining or when one is cut or burned from dirt or insufficient lubrication.

Clean carbon from pistons and cylinders and free any rings that may be stuck in the groove. Lap all valves that leak, being careful to leave no ridges on either valve or seat. Clean and oil carefully all parts when reassembling.

Carburetion

If adjustment of carbureter is found necessary it should be attempted only by one thoroughly competent, and strictly according to the instruction pamphlet issued by the maker of the carbureter. If the instruction pamphlet should be lost a new copy can be had for the asking. It will be well to give the name and model of the carbureter in making inquiry.

The Trouble Chart

This chart has been prepared to outline in a simple manner the various troubles that interfere with the efficient action of aëronautical motors.

The various defects that may develop are tabulated in a manner that makes for ready reference, and opposite the part affected the various conditions are found under a heading that denotes the main trouble to which the others are contributing causes.

The various symptoms denoting the individual troubles outlined are given to facilitate their recognition in a positive manner. Brief note is also made of the remedies for the restoration of the defective part or condition.

It is apparent that a chart of this kind is intended merely as a guide, and it is a compilation of practically all the known troubles that may materialize in gas-engine operation. While most of the defects outlined are common enough to warrant suspicion, all will never exist in an engine at the same time; and it will be necessary to make a systematic search for such of those as do exist, and by the process of elimination locate the offending part.

To use the chart advantageously it is necessary to know and recognize easily one main trouble. For example, if the motor is skipping, look for possible troubles under the heading "Skipping." If the motor fails to develop power, the trouble will undoubtedly be found under "Lost Power and Overheating."

It is assumed in all cases that the trouble exists in the power plant or its components, and not in the auxiliary members of the ignition. In many instances, however, the seat of trouble will be traced to these latter members.

Skipping or Irregular Operation

Part at fault	Trouble	Effect	Remedy
1 Spark plug	Loose binding at post Leak in threads Defective gasket Cracked insulator Points too close Points too far apart Carbon deposit Plug too long	No spark Low compression Low compression Short-circuit No spark No spark No spark Pre-ignition	Tighten terminal Screw down tighter Replace with new plug Replace with new plug Set points apart Set points closer Clean off points and plug Change plug
2 Combustion chamber	Carbon deposit	Pre-ignition	Remove carbon
3 Piston head	Carbon deposit Crack or blowhole (rare)	Pre-ignition Pre-ignition	Remove carbon Replace with new
4 Valve head	Warped or pitted on seat	Poor mixture Low compression	True up in lathe and grind to seat Replace with new
5 Valve stem	Binds in guide Sticks	Irregular valve action	Clean guide Straighten stem Oil
6 Valve spring	Weakened or broken	Irregular valve action	Replace with new
7 Exhaust valve seat	Scored or warped Dirty or covered with scale	Valve will not close Poor mixture Poor compression	Use reseat reamer Clean off and grind to seat
8 Exhaust valve-stem guide	Warped or carbonized Worn guide	Valve stem sticks Low compression Poor seating Poor mixture	Clean guide or new guide
9 Valve-stem clearance	Too little Too much	Valve will not shut Valve opens late and closes early	Set inlet gap 0.010 Set exh. gap 0.010
10 Camshaft bearing	Looseness or wear	Valves mistimed or valve lift short	Replace with new bushing
11 Cam	Worn contour	Valve lift short Valves mistimed	Replace with new camshaft

Skipping or Irregular Operation.—(*Continued*)

Part at fault	Trouble	Effect	Remedy
12 Timing gear	Not properly meshed Loose on shaft Worn or broken tooth	Valves mistimed Valves do not act	Time properly Fasten to shaft With key Replace with new gear
13 Cam-follower guide	Loose on engine base Lock pin sheared off Worn in bore	Oil leaks Poor valve action	Fasten securely New pin New guide or bushing
14 Cam follower	Loose in guide	Valves mistimed Oil leak	Replace with new guide or bushing
15 Inlet valve	Closes late Opens early	Blowback in carbureter	Time properly
16 Inlet-valve seat	Warped or pitted Does not seat properly Carbon grain under seat	Blowback in carbureter Low compression	Use reseat reamer Clean off and grind to seat
17 Inlet-valve stem guide	Worn	Poor mixture Low compression	Bush or replace with new guide
18 Carbureter	Weak mixture	Blowback in carbureter	Adjust carbureter for richer mixture
19 Gas manifold pipe	Leak at joints Defective gasket Crack or blowhole	Poor mixture Poor mixture Poor mixture	Stop all leaks Replace with new Solder blowhole
20 Piston	Walls scored	Poor suction and leak of gas	Smooth up
21 Piston rings	Loss of spring Loose in grooves Worn or broken Slots in line	Poor suction and leak of gas Poor compression	Peen rings or replace with new Loosen rings on piston
22 Cylinder wall	Scored by wristpin Scored by lack of oil	Poor suction and leak of gas Poor compression	Lap in cylinder Or new cylinder
23 Valve-spring collar key	Broken	Release spring No valve action	Replace with new key

Lost Power and Overheating

Part at fault	Trouble	Effect	Remedy
24 Manifold connections	Poor mixture in one set of cylinders with good mixture in other set	Surging or pulsating	Tighten connections; put in new gaskets
25 Water-pipe joint	Loose Defective gasket	Loss of water and overheating	Tighten bolts or replace with new connection
26 Spark plug	Loose in threads Defective gasket	Poor compression and overheating	(See No. 1) Screw down tight Replace with new
27 Combustion chamber	Crack or blowhole Roughness Carbon deposit	Poor compression Pre-ignition Pre-ignition	Fill by welding or replace with new Smooth up Remove carbon
28 Valve-head	Warped, scored, or pitted Carbonized or covered with scale	Poor compression	True up in lathe and grind to seat Scrape off smooth with emery cloth
29 Valve seat	Warped or pitted Carbonized or covered with scale	Poor compression or blowback	Use reseat reamer Clean off and grind to seat
30 Piston rings	Loss of spring Loose in groove Worn or broken Slots in line	Poor suction, leak of gas, and overheating Poor compression	Peen rings or replace with new Loosen rings on piston
31 Piston rings	Broken because too tight Insufficient opening	Scored cylinder walls, overheating in sump pan, and poor compression	Replace scored cylinder if groove is deep; use new rings
32 Wristpin	Loose Scored cylinder	Poor compression	Fasten securely Replace scored cylinder if groove is deep
33 Piston head	Carbon deposit Crack or blowhole (rare)	Pre-ignition Poor compression	Remove carbon Replace with new
34 Piston	Binds in cylinder Walls scored or worn out of round	Overheating	Lap off excess metal Replace with new

LOST POWER AND OVERHEATING.—(*Continued*)

Part at fault	Trouble	Effect	Remedy
35 Cylinder wall	Scored Poor lubrication causes friction	Poor compression and overheating	Replace with new Lap in cylinder Repair oiling system
36 Camshaft Drive gear	Loose on shaft Not properly meshed Worn or broken teeth	Irregular valve action	Fasten to shaft Time properly Replace with new
37 Crankshaft	Scored or rough on journals Sprung	Overheating Overheating	Smooth up Straighten
38 Crankpin Bearings and main bearings	Adjusted too tight Defective oiling	Overheating	Adjust to running clearance Clean out oil holes
39 Oil sump	Insufficient oiling Poor oil Dirty oil	Overheating and burned-out bearings	Replenish supply Use best oil—Mobile "A" recommended Wash with kerosene Replace with new oil
40 Water space and water pipes	Clogged with sediment or scale	Overheating	Dissolve and remove foreign material
41 Radiator hose	Layer of hose obstructs opening	Overheating	Refit or replace with new
42 Water pump	Impeller loose on shaft Dirty Broken	Overheating	Fasten to shaft Clean Replace with new

NOISY OPERATION

Part at fault	Trouble	Effect	Remedy
43 Spark plug	Leakage	Hissing	Screw down tighter Replace with new
44 Cylinder wall	Scored	Knocking	Smooth up or replace with new
45 Manifold pipe joints	Leakage Defective gaskets	Sharp hissing	Tighten bolts Replace with new
46 Combustion chamber	Carbon deposit	Knocking	Remove carbon
47 Cylinder casting	Retaining bolts loose	Sharp metallic knock	Tighten bolts
48 Cam	Worn contour	Metallic knock	Replace with new
49 Piston head	Carbon deposit	Knock	Remove carbon
50 Wristpin	Loose in piston Worn	Dull metallic knock	Replace or bush
51 Connecting rod	Worn at wristpin or crankshaft Sideplay in piston	Distinct knock	Adjust or replace Scrape and fit and oil
52 Main crankshaft bearing	Loose Defective lubrication	Metallic knock Squeak	Fit caps close to shaft Clean out oil holes and oil
53 Connecting-rod bearings	Loose Excessive play Binding	Intermittent metallic knock Knock and squeak	Refit Reline
54 Connecting-rod bolts, main-bearing bolts	Loose Stripped threads	Sharp knock	Tighten Replace bolts

NOISY OPERATION.—(*Continued*)

Part at fault	Trouble	Effect	Remedy
55 Lower half Crank-case bolts	Loose Stripped threads	Knock and rattle	Tighten New bolts
56 Water jacket	Covered with scale Clogged with dirt	Knock caused by overheating	Dissolve scale and flush out water space with water under pressure
57 Timing gears	Loose Worn or broken teeth Meshed too deeply	Metallic knock Rattle Grinding	Fasten to shaft Replace with new gear
58 Camshaft bearing	Loose or worn	Slight knock	Replace with new
59 Inlet-valve seat	Warped or pitted Dirty	Rattle Poor compression Blowback	Use reseat reamer Clean off and grind to seat
60 Inlet-valve spring	Weak or broken	Blowback in carbureter	Replace with new
61 Inlet valve	Closes late Opens early	Blowback in carbureter	Time properly
62 Valve-stem guide	Worn or loose	Rattle or click	Replace with new guide
63 Cam-follower guide	Loose	Rattle or click	Replace with new guide
64 Valve-stem clearance	Too much Too little	Click Blowback in carbureter	Set inlet gap 0.010 Set exh. gap 0.010
65 Push-rod retention stirrups	Nuts loose	Rattle Blowback in carbureter	Tighten nuts
66 Crank-case gaskets	Leak	Oil leak	Tighten bolts Replace with new
67 Cylinder or piston	No oil Poor oil	Grinding and sharp knock	Repair oil system Use best oil

Noisy Operation.—(*Continued*).

Part at fault	Trouble	Effect	Remedy
68 Piston	Binding in cylinder Worm oval causing side slap	Grind or dull squeak Dull hammer	Lap off excess metal Replace with new
69 Oil sump	Insufficient oil Poor oil	Grind and squeak in all bearings	Replenish with best oil
70 Piston rings	Defective oiling	Squeak, hiss, grind	Replace with new ring Repair oil system
71 Crankshaft	Defective oiling	Squeak	Clean out oil holes Use best oil Repair oil system
72 Engine base	Loose on frame	Dull pound	Tighten bolts
73 Water pipe	Leak Clogged Defective gaskets	Engine heats	Tighten connections Clean Replace with new

Important Dont's

1. Don't forget that "A stitch in time saves nine."
2. Don't forget to inspect the motor thoroughly before starting.
3. Don't try to start without oil, water, or gasoline; all three are vital.
4. Don't forget to see that the radiator is full of water.
5. Don't get dirt or water into the oil.
6. Don't get dirt or water into the gasoline.
7. Don't forget to oil all exposed working parts.
8. Don't try to start without retarding the magneto; a serious accident may result.
9. Don't try to start without turning on the switch.
10. Don't start the motor with throttle wide open.
11. Don't run the motor idle too long; it is not only wasteful but harmful.
12. Don't forget to watch the lubrication; it is most essential.
13. Don't forget that the propeller is the business end of the motor; treat it with profound respect—especially when it is in motion.
14. Don't cut off the ignition suddenly when the motor is hot; allow it to idle for a few minutes at low speed before turning off the switch. This

insures the forced circulation of the water till the cylinder walls have cooled considerably and also allows the valves to cool, preventing possible warping.

15. Don't fail to study the trouble charts in this book before you molest a thing about the motor, if you have trouble.

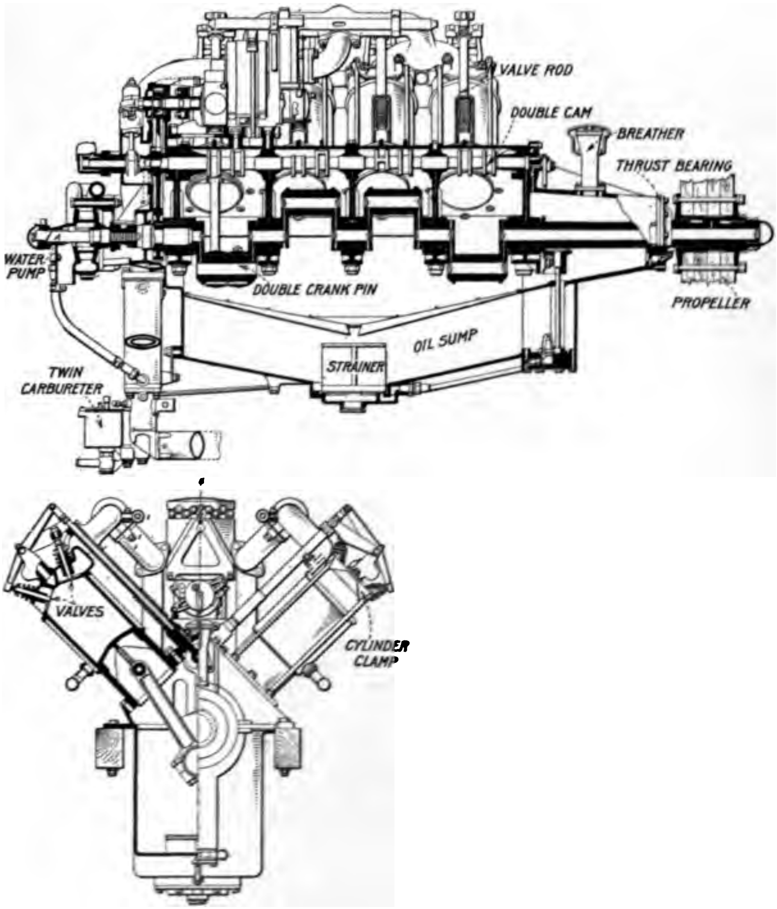


FIG. 60.—Section view of Curtiss engine.

16. Don't develop that destructive disease known as tinkeritis; when the motor is working all right, let it alone.

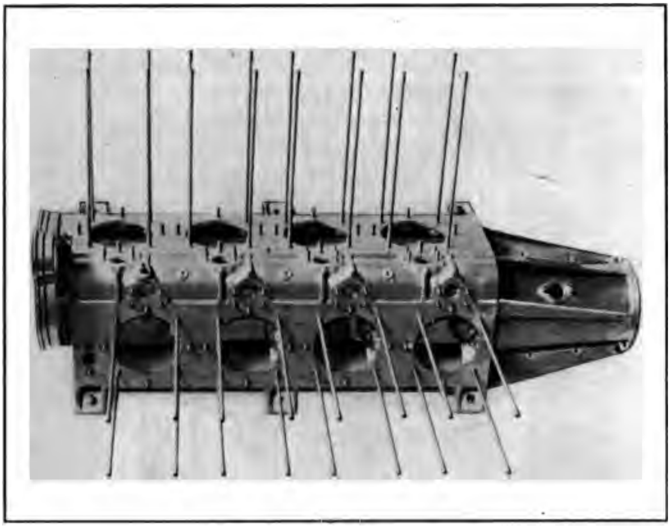


FIG. 61 —Engine base with studs.

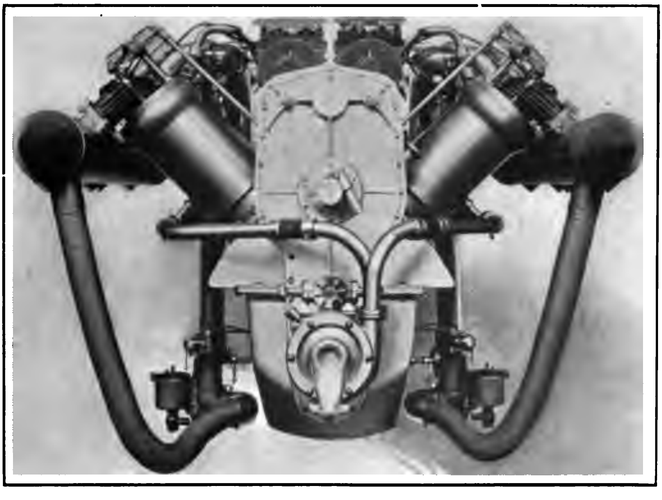


FIG. 62.—End view of Curtiss engine.

17. Don't forget a daily inspection of all bolts and nuts. Keep them well tightened.

18. Don't fail to stop your motor instantly upon detecting a knock, a grind, or other noise foreign to perfect operation. It may mean the difference between saving or ruining the motor.

19. Don't fail to study these instructions thoroughly.

A sectional view of the Curtiss engine is shown in Fig. 60 and the cylinder base with all the studs in position is shown in

FIG. 63.—Fitting piston pin.

Fig. 61. The short studs simply project through the cylinder flange while the long studs go through a cross-tie at the top of the cylinder. An end view is shown in Fig. 62.

The piston pin bears in the aluminum piston itself and as the

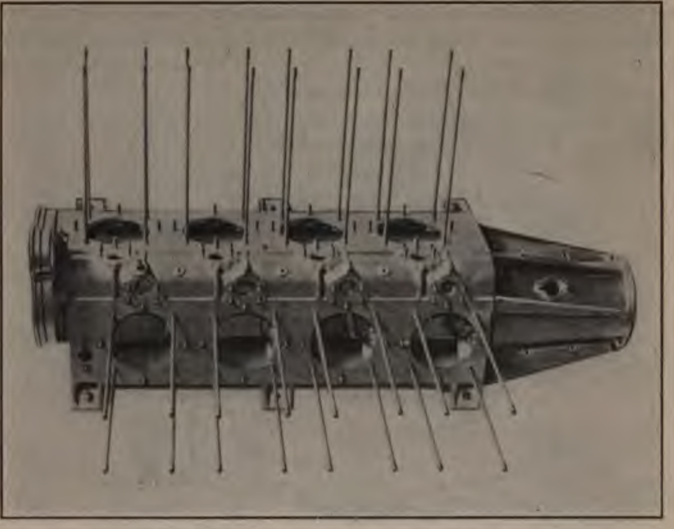


FIG. 61.—Engine base with studs.

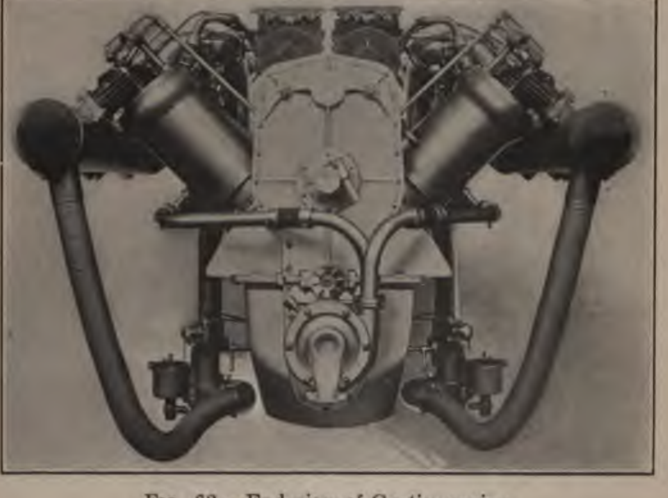


FIG. 62.—End view of Curtiss engine.

fixture on which the large end is held as shown. Then a rod is put through the piston-pin hole and any slight correction made. The rod is then swung over so the rod comes into con-

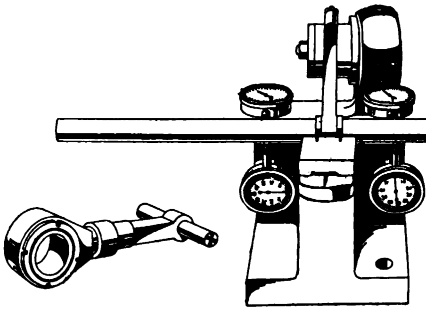


FIG. 65.

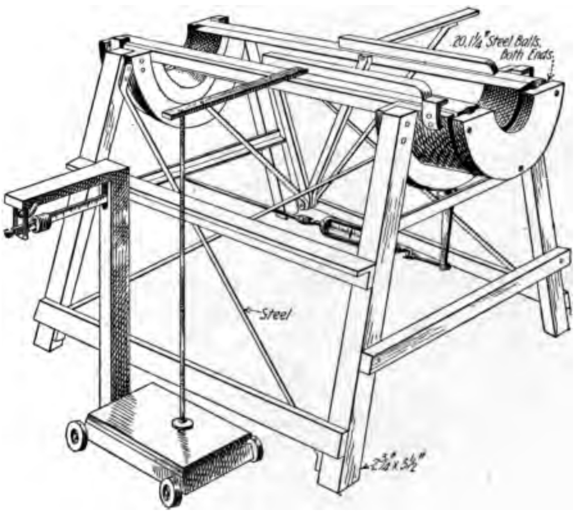


FIG. 66.—Curtiss testing stand.

tact with the four Ames dial gages and shows when the rod is straight as in Fig. 65. Standard rods used for testing are shown in both cases.

piston expands more than the pin, it is necessary to make the pin a tight fit when the parts are cold. In order to secure uniformity in this the fit is "weighed" as shown in Fig. 63. Here the piston is held in suitable jaws to prevent marring or springing and the fit tested by using a spring balance as shown. This,

FIG. 64.—Straightening connecting rods.

when hooked into the upper end of the rod, must move the pin with a pull of 12 pounds.

When connecting rods are bent or twisted out of line they can be straightened as shown in Fig. 64. This is a substantial fixture on which the large end is held as shown. Then a rod is put through the piston-pin hole and any slight correction made. The rod is then swung over so the rod comes into con-

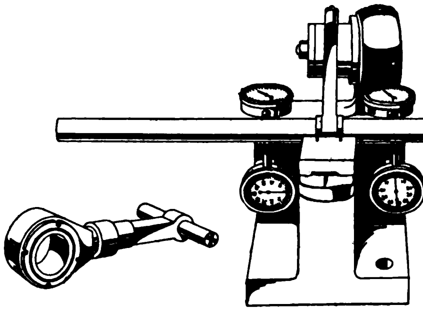


Fig. 65.

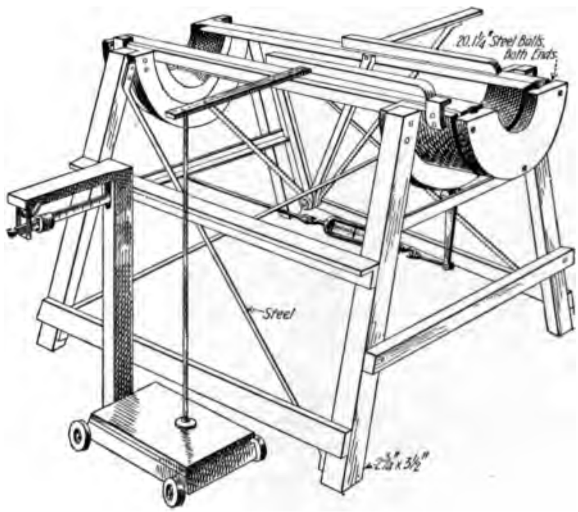


Fig. 66.—Curtiss testing stand.

tact with the four Ames dial gages and shows when the rod is straight as in Fig. 65. Standard rods used for testing are shown in both cases.

After the engine is assembled it is tested on the stand shown in Fig. 66, which can show both torque and thrust. The engine sets in a cradle mounted on ball bearings and free to turn or move forward a limited amount. The turning effort or torque, is measured by the platform scale and the thrust by the spring balance shown in Fig. 66.

SECTION IX

CARE AND OPERATION HALL-SCOTT AIRPLANE ENGINES

The Hall-Scott engine is a six-cylinder vertical type and is being largely used in training machines. Those in charge of the engine should observe the following suggestions.

To Insure Maximum Service.—The following instructions should be carried out after every long flight. If used for schooling purposes, daily care should be taken, as follows:

While engine is still warm remove all spark plugs.

Clean each plug with gasoline and a stiff brush, and space each plug with proper 0.015-inch gage.

Remove lower crank-case sump plug, and drain oil into a clean measure, cover same and allow to stand until morning.

Clean out lower crank case thoroughly with gasoline or kerosene.

Squirt gun full of kerosene into each cylinder through spark-plug opening.

Remove front portion magneto distributor cover and wipe out distributor block with soft cloth, moistened in alcohol if necessary.

In replacing distributor block be sure to wipe off all excess oil on magnetos and covers before replacing.

Cover engine for night with canvas or heavy cloth.

To Prepare Engine for Service.—Turn engine over a few times and note that all working parts are perfectly free.

Replace lower oil sump.

Pour off top of oil left to stand over night, into a clean measure, making sure that the heavier portion of oil and carbon deposit is left in first measure. Add to the second measure enough new oil to make 2½ to 3 gallons.

Pour oil into sump through breather pipe lead.

Replace spark plugs and connect lead wires.

The engine is now ready to start. Run slowly with engine throttled for at least 10 minutes while the plane is on the ground, before starting on flight, so that the lubricating oil will have a chance to work up on the cylinders and pistons.

Standard Adjustments

Spark plugs should have 0.015-inch clearance between points across which the spark jumps.

Magneto Breaker Points.—Gap between breaker points in *Dixie Magnetos* when full open should be 0.020. Use gage furnished with each magneto screw-driver. It might be possible to obtain better results if the breaker gap is closed to 0.018. We recommend trying the gap with a 0.020 adjustment; if the motor misses at high speeds readjust to 0.018, which possibly will give better results.

Oil Pressure.—Oil pressure will vary according to weather conditions and gravity of oil used. In normal weather with engine properly warmed up, the pressure will register upon the oil gage from **5 to 10 pounds** when engine is turning from 1275 to 1300 r.p.m.

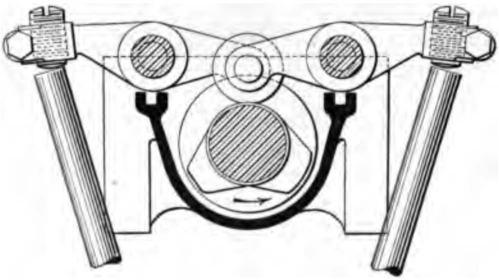


Fig. 67.—Valve clearances.

Air Pressure.—Air-pressure gage should not register under 3 pounds.

Valve Clearances.—Inlet and exhaust valves should be set with a full 0.020-inch clearance *when engine is cold* (see Fig. 67). This should be checked by a Hall-Scott timing disc.

Gear Clearances.—With the exception of the lower pinion shaft gear meshing with the crankshaft, which has a 0.010-inch clearance, all other gears have a 0.020-inch clearance.

Bearing Clearances.—Crankshaft bearings should have a 0.001-inch clearance.

Connecting rods should be set up snug, allowing enough clearance, however, so that the rod may be slid laterally on the crankskaft bearing without binding.

Lubrication System.—The proper lubrication of all airplane engines is of vital importance.

Oils best adapted for Hall-Scott engines have the following properties: A flash test of not less than 400°F.; viscosity of not less than 75 to 85 taken at 212°F. with Saybolts Universal Viscosimeter. The makers suggest:

Zeroline heavy-duty oil, manufactured by the Standard Oil Co. of California, or

Gargoyle mobile B oil, manufactured by the Vacuum Oil Co. Both fulfill the above specifications. One or the other of these oils can be obtained all over the world.

Monogram extra heavy is also recommended.

Do not experiment with other oils without first obtaining the approval of the makers.

Engine Oiling System.—Crankshaft, connecting rods and all other parts within the crank case and cylinders are lubricated directly or indirectly by a force-feed oiling system. The cylinder walls and wristpins are lubricated by oil spray thrown from the lower end of connecting-rod bearings. Fig. 68 shows engine partially in section.

This system is used only upon A-5 engines. Upon A-7a and A-5a engines a small tube supplies oil from connecting-rod bearing directly upon wristpin.

Engine Oiling Circulation.—The oil is drawn from the strainer located at the lowest portion of the lower crank case, forced around the main intake manifold oil jacket. From here it is circulated to the main distributing pipe located along the lower left-hand side of upper crank case. The oil is then forced directly to the lower side of crankshaft through holes drilled in each main bearing cap. Leakage from these main bearings is caught in scuppers placed upon the cheeks of the crankshafts furnishing oil under pressure to the connecting-rod bearings. A-7a and A-5a engines have small tubes leading from these bearings which conveys the oil under pressure to the wristpins.

Bypass.—A bypass located at the front end of the distributing oil pipe can be regulated to lessen or raise the pressure. By screwing the valve in, the pressure will raise and more oil will be forced to the bearings. By unscrewing, pressure is reduced and less oil is fed.

A-7a and A-5a engines have oil relief valves located just off of the main oil pump in the lower crank case. This regulates the pressure at all times so that in cold weather there will be no danger of bursting oil pipes due to excessive pressure. If it is found that the oil pressure is not maintained at a high enough level inspect this valve. A stronger spring will not allow the oil to bypass so freely and consequently the pressure will be raised, a weaker spring will bypass more oil and reduce the oil pressure materially.

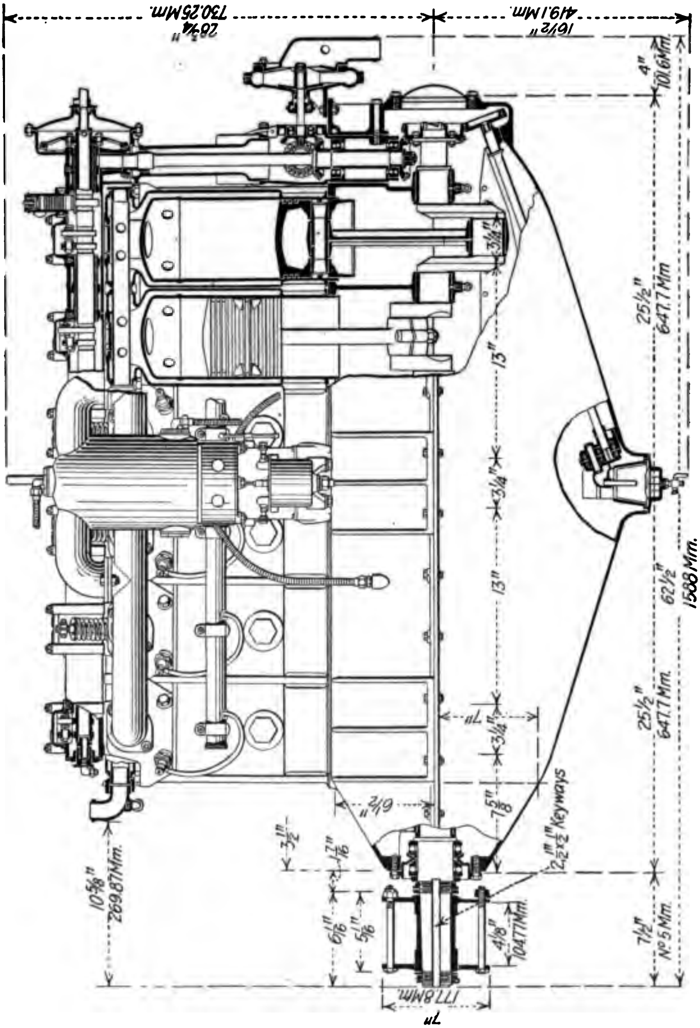


FIG. 68.—Hall-Scott engine.

Auxiliary Oil Distributor (Used upon a A-5 Engines Only).—Independent of the above-mentioned system, a small, directly driven rotary oiler feeds oil to the base of each individual cylinder. The supply of oil is furnished by the main oil pump located in the lower crank case. A small sight-feed regulator is furnished to control the supply of oil from this oiler.

Auxiliary Oil Distributor Sight-feed Regulator (Furnished with A-5 Engines Only).—This instrument should be placed higher than the auxiliary oil distributer itself to enable the oil to drain by gravity feed to the oiler. If there is no available place with the necessary height in the front seat of plane, connect it directly to the intake *L* fitting on the oiler in an upright position. It should be regulated with full open throttle to maintain an oil level, approximately half way in the glass.

Oil Dash Pressure Gage.—An oil pressure gage is provided. This should be run to the pilot's instrument board. The gage registers the oil pressure upon the bearings, also determining its circulation. Strict watch should be maintained of this instrument by pilot, and if for any reason its hand should drop to *O* the motor should be immediately stopped and the trouble found before restarting engine.

Care should be taken that the oil does not work up into the gage as it will prevent the correct gage registering of oil pressure.

Oil Sump Plug.—The oil sump plug is located at the lowest point of the lower crank case. This is a combination dirt, water and sediment trap. It is easily removed by unscrewing.

Oiling Camshaft Housing.—Oil is furnished mechanically to the camshaft housing under pressure through a small tube leading from the main distributing pipe at the propeller end of engine directly into the end of camshaft housing. The opposite end of this housing is amply relieved to allow the oil to rapidly flow down upon camshaft, magneto, pinion shaft, and crankshaft gears, after which it returns to lower crank case. An outside overflow pipe is also provided to carry away the surplus oil.

Draining Oil from Crank Case.—The oil strainer is placed at the lowest point of the lower crank case. This strainer should be removed after every 5 to 8 hours running of the engine and cleaned thoroughly with gasoline. It is also advisable to squirt distillate up into the case through the opening where the strainer has been removed.

Allow this distillate to drain out thoroughly before replacing the plug with strainer attached. Be sure gasket is in place on plug before replacing.

Pour new oil in through either of the two breather pipes on exhaust side of motor. Be sure to replace strainer screens if removed.

Insufficient Lubrication.—If, through oversight, the engine does not receive sufficient lubrication and begins to heat or pound, it should be stopped immediately. After allowing engine to cool pour at least 3 gallons of oil into oil sump. Fill radiator with water after engine has cooled. Should there be apparent damage, the engine should be thoroughly inspected immediately without further running. If no obvious damage has been done, the engine should be given a careful examination at the earliest opportunity to see that the running without oil has not burned the bearings or caused other trouble.

Special Auxiliary Oil Tank.—Special auxiliary oil tanks can be supplied for long flights. This tank, if used upon A-5, A-7 or A-7a engines, should be placed slightly higher than the lowest point of the engine oil sump, thus allowing new oil if required to flow from this tank into the main sump, so that the oil will flow by gravity through the lead pipe to main oil sump on engine. The crank-case oil sump has a capacity sufficient for from 3 to 6 hours flight, depending entirely upon weather conditions, kind of oil used and r.p.m. of engine. For special military purposes auxiliary tanks can be furnished for flights of any duration. The A-5a engine is fitted with a double oil pump. One is for the main oil supply, the second has a lead to the side of the lower crank case. By leading a tube from this to an auxiliary oil tank, fitted with a shutoff cock, the pump will suck oil into the main sump when desired by the operator.

Gasoline System.—In filling the tanks, pour the gasoline through a chamois skin to free it from water and impurities. Each gasoline tank should be equipped with a dirt and water trap. It is imperative to install the water trap furnished with each equipment in the gasoline line. The gasoline pipe from tank to carbureter should be installed at the rear of the tank so gasoline will always be supplied when climbing.

Gasoline.—Gasoline giving the best results with our equipments is as follows:

Gravity 58° to 62°Bé. A. Initial boiling point—Richmond method—102°F.

Sulphur 0.014.

Calorimetric bomb test 20,610 B.t.u. per pound.

Pressure Gasoline Feed.—If the gasoline tank is placed in the fuselage below the level of the carburetor, a hand pump must be used to maintain air pressure in gas tank to force the gasoline to the carbureter. After starting the engine the small auxiliary air pump upon the engine will maintain sufficient pressure.

Auxiliary Air Pump.—A-7a and A-5a engines are furnished with a new type auxiliary air pump. This should be frequently oiled and care taken so no grit or sand will enter which might lodge between the valve and its seat, which would make it fail to operate properly.

Air Relief Valve.—One of these are furnished with each engine. It should be screwed into the gas tank and properly regulated to maintain the pressure required. This is done by screwing the ratchet on top either up or down. If two tanks are used in a plane one should be installed in each tank.

Air Pump Lines.—All air pump lines should be carefully gone over quite frequently to ascertain they are tight. Check valves have to be placed in these lines.

Gravity-feed Gasoline Supply.—In some cases the gasoline tank is placed above the engine, allowing it to drain by gravity to the carbureter. When using this system there should be a drop of not less than 2 feet from the lowest portion of the gasoline tank to the upper part of the carbureter float chamber. Even this height might not be sufficient to maintain the proper volume of gasoline to the carburetor at high speeds. We recommend air pressure upon all tanks to insure the proper supply of gasoline. When using gravity feed without air pressure be sure to vent the tank to allow circulation of air. If gravity tank is used and the engine runs satisfactorily at low speeds but cuts out at high speeds the trouble is undoubtedly due to insufficient height of the tank above the carbureter. The tank should be raised or air pressure system used.

Intake Manifold.—Care should be taken to see that the flanges of the intake manifold are tightly drawn up against the gasket and cylinder intake ports. If there is an air leak at any of these connections it will affect the mixture in the respective cylinder, as well as make it exceedingly hard to start.

Carbureter.—Care should be taken to ascertain that all nozzles are tight on the carbureter. On the A-5 and A-5a engines the top of jets must be level with top of well to allow equal distribution of fuel to each set of cylinders. These can be easily adjusted by washer on lower portion of jet. The standard equipment of the carbureter is as follows, using commercial gasoline of 58° to 62°Bé. gravity and under moderate weather conditions:

	A-5 No.	A-5a No.	A-7 No.	A-7a No.
Choke	31	31	30	31
Jet	140	145	140	145
Compensator	160	165	160	165
Well	60	60	60	60

If high-test gasoline is used, namely, 70° or 72°, or extremely hot weather is encountered, it may be advisable to change the size of the jets to No. 135 upon the A-5 and proportionately upon the other types. In extremely cold weather better results can be obtained by changing jets to No. 145.

Two jets and two compensators are used in each carbureter on A-5 and A-5a types.

This Duplex Model O. D. Zenith carbureter used upon the six-cylinder engines consists of a single float chamber, and a single air intake, joined to two separate and distinct spray nozzles, venturi and idling adjustments. It is to be noted that as the carbureter barrels are arranged side by side, both valves are mounted on the same shaft, and work in unison through a single operating lever. It is not necessary to alter their position.

In order to make the engine idle well, it is essential that the ignition, especially the spark plugs, should be in good condition. The gaskets between carbureter and manifold, and between manifold and cylinders should be absolutely air-tight. The adjustment for low speed on the carbureter is made by turning in or out the two knurled screws, placed one on each side of the float chamber. After starting the engine and allowing it to become thoroughly warmed, one side of the carbureter should be adjusted so that the three cylinders it effects fire properly at low speed. The other side should be adjusted in the same manner until all six cylinders fire perfectly at low speed.

As the adjustment is changed on the knurled screw a difference in the idling of the engine should be noticed. If the engine begins to run evenly or speeds up it shows that the mixture becomes right in its proportion.

Be sure the butterfly throttle is closed as far as possible by screwing out the stop screw which regulates the closed position for idling. Care should be taken to have the butterfly held firmly against this stop screw at all times while idling engine. If three cylinders seem to run irregularly after changing the position of the butterfly, still another adjustment may have to be made with the knurled screw. Unscrewing this makes the mixture leaner. Screwing in closes off some of the air supply to the idling jet, making it richer. After one side has been made to idle satisfactorily repeat the same procedure with the opposite three cylinders. In other words, each side should be idled independently to about the same speed.

Remember that the main jet and compensating jet have no appreciable effect on the idling of the engine. The idling mixture is drawn directly through the opening determined by the knurled screw and enters the carbureter barrel through the small hole at the edge of each butterfly. This is called the priming hole and is only effective during idling. Beyond that point the suction is transferred to the main jet and compensator, which controls the power of the engine beyond the idling position of the throttle.

Water in the Gasoline.—A very few drops of water lodged in the bottom of the unions will suffice to produce transient difficulties in carburetion. Assuming the amount of water to be very small, the trouble may be remedied by taking out the two hexagon nuts under the jets and emptying the carbureter.

Ignition System.—The ignition system upon four-cylinder engines is supplied by two "*Dixie*" model 46 magnetos. The A-5 is supplied by two "*Dixie*" 68 magnetos. These are fully described in a booklet issued by the Splitdorf Electrical Co. It is most important that after every long flight, the distributor block be detached and wiped off with a soft cloth. The carbon brush leaves a deposit where it runs between the contact points, which often enables the spark to jump across, causing the motor to miss fire, run roughly, or premature fire. If this deposit cannot be removed with a dry cloth, it is advisable to moisten the cloth with gasoline. This will clean the surface, leaving it smooth, which is essential.

It is highly advisable to remove all twelve of the spark plugs at least once a week and space them properly. The gap between the points when using "*Dixie*" magnetos should be 0.015 inch (fifteen one-thousandths).

It is not necessary to advance the "*Dixie*" magnetos to start the engine; they should be retarded.

Two "*Dixie*" switches are furnished with each engine. Both of these should be installed in the pilot's seat, one controlling the right-hand and the other the left-hand magneto. By shorting either one or the other it can be quickly determined if both magnetos, with their respective spark plugs, are working correctly.

Spark Plugs.—Care should be taken not to use spark plugs having *special extensions or long protruding points*. Plugs giving best results are extremely small with short points.

Temperature Gage.—A temperature gage should be installed in the water pipe, coming directly from the cylinder nearest the propeller. This instrument installed in the radiator cap has not always given satisfactory results. This is especially noticeable when the water in the radiator becomes low, not allowing it to touch the bulb on the moto-meter.

For ordinary running, it should not indicate over 150°F. In climbing tests, however, a temperature of 160°F. can be maintained without any ill effects upon the engine.

In case the engine becomes overheated, the indicator will register above 180°F., in which case it should be stopped immediately. Overheating is most generally caused by retarded spark, excessive carbon in the cylinders, insufficient lubrication, improperly timed valves, lack of water, clogging of water system in any way which would obstruct the free circulation of the water.

Overheating will cause the engine to knock, with possible damaging results.

Suction pipes should be made out of thin tubing, and run within $\frac{1}{4}$ or $\frac{1}{8}$ inch of each other, so that when a hose is placed over the two, it will not be

HALL-SCOTT AIRPLANE ENGINE STATISTIC SHEET

Type of Engine	A-7	A-7a	A-5	A-5a
Rated horsepower	90	100	125	150
R.p.m. at which hp. is rated	1,300	1,300	1,300	1,300
Hp. to be reasonably expected after engine is well run in	100	110	135	160
Net weight, pounds	410	405	565	590 578
R.p.m. recommended for normal flying conditions	1,250	1,250	1,250	1,250
Safe max. r.p.m. at which engine can be operated	1,350–1,400	1,250–1,400	1,300–1,350	1,300–1,350
Min. gasoline consumption in gal. per hour at 1300 r.p.m.	9	10	12½	15
Same, figured in pounds per b.hp.-hour	0.58	0.58	0.58	0.58
Gasoline consumption in gal. per hour at 1300 r.p.m. to be reasonably expected, with well run in engine	8½	9½	12½	14½
Same, figured in pounds per b.hp.-hour	0.552	0.543	0.576	0.565
Oil consumption in gal. per hour	0.58	0.50	0.58	0.50

HALL-SCOTT AIRPLANE ENGINE STATISTIC SHEET—(*Continued*)

Type of Engine	A-7	A-7a	A-5	A-5a
Same, figured in pounds per b.hp.-hour	0.051	0.035	0.040	0.025
Oil consumption to be reasonably expected with well run in engine in gal. per hour	0.48	0.35	0.45	0.35
Estimated cooling water required (governed by position of radiator)	5.75	6.50	8.00	9.50
Weight of same in pounds	46.7	52.8	65.0	77.2
Max. radiating surface required, front surface of core (for front-type radiator), square inches	360	400	500	600
Same (for single radiator mounted just below top center section of plane)	290	320	400	980
Same (for pair side radiators)	500	560	700	840
Diameter pitch of propeller recommended for general use	D—8′ 3″ P—5′ 3″	D—8′ 4″ P—6′ 0″	D—8′ 10″ P—6′ 3″	D—9′ 0″ P—6′ 6″
Highest temperature cooling water within safe operation of engine	160°F.	160°F.	160°F.	160°F.

possible to suck together. This is often the case when a long rubber hose is used, which causes overheating. Radiators should be flushed out and cleaned thoroughly quite often. A dirty radiator may cause overheating.

Water Circulation.—When filling the radiator it is very important to remove the plug on top of the water pump until water appears. This is to avoid air pockets being formed in the circulating system, which might not only heat up the engine, but cause considerable damage.

All water-pump hoses and connections should be tightly taped and shellaced after the engine is properly installed in the plane.

The greatest care should be taken when making engine installation **not** to use smaller inside diameter hose connection than water-pump suction end casting. One inch and a quarter inside diameter should be used on A-7 and A-5 motors, while nothing less than 1½ inches inside diameter hose or tubing on all A-7a and A-5a engines. It is further important to have light spun tubing, void of any sharp turns, leads from pump to radiator and cylinder water outlet to radiator. In other words, the water circulation through the engine must be as little restricted as possible. Be sure no light hose is used, that will often suck together when engine is started.

Draining the Water System.—To thoroughly drain the water from the entire system, open the drain cock at the lowest side of the water pump.

Preparation to Start Engine.—Always replenish gasoline tanks through a strainer which is clean. This strainer must catch all water and other impurities in the gasoline.

Pour at least 3 gallons of fresh oil into the lower crank case.

Oil all rocker-arms through oilers upon rocker-arm housing caps.

Be sure radiators are filled within 1 inch of the top.

After all the parts are oiled, and the tanks filled, the following must be looked after before starting:

See if crankshaft flange is tight on shaft.

See if propeller bolts are tight and evenly drawn up.

See if propeller bolts are wired.

See if propeller is trued up to within ⅛ inch.

Every 4 days the magnetos should be oiled if the engine is in daily use.

Every month all cylinder hold-down nuts should be gone over to ascertain they are tight. (Be sure to re-cotter nuts.)

See if magnetos are bolted on tight and wired.

See if magneto cables are in good condition.

See if rocker-arm tappets have a 0.020-inch clearance from valve stem when valve is seated.

See if tappet clamp screws are tight and cottered.

See if all gasoline, oil, water pipes and connections are in perfect condition.

Air on gas line should be tested for leaks.

Pump at least 3 pounds air pressure into gasoline tank.

After making sure that above rules have been observed, test compression of cylinders by turning propeller.

"Do Not Forget to Short Both Magnetos."—Be sure all compression release and priming cocks do not leak compression. If they do, replace same with a new one immediately, as this might cause premature firing.

Open priming cocks and squirt some gasoline into each.

Close cocks.

Open compression release cocks.

Open throttle slightly.

If using Berling magnetos they should be three-quarters advanced.

If all the foregoing directions have been carefully followed, the engine is ready for starting.

In cranking engine either by starting crank, or propeller, it is essential to throw it over compression quickly.

Immediately upon starting, close compression release cocks.

When engine is running, advance magnetos.

After it has warmed up, "short" one magneto and then the other, to be sure both magnetos and spark plugs are firing properly. If there is a miss, the fouled plug must be located and cleaned.

Do Not Accelerate Engine Until It Has Been Warmed up Thoroughly.—The oil gage provided is an exceedingly delicate instrument which can easily be broken by excessive pressure caused by rapid acceleration of a cold engine. Care should be taken to see that oil does not get up inside of gage which will stop it up, usually making the hand drop to zero.

In cold weather we recommend covering up the radiator until the temperature of the water reaches 80° to 100°F.

To Stop Engine.—Before stopping engine, let it run slowly for a minute or two, then short magnetos. We recommend, after a long run, while the engine is still hot, to squirt kerosene through the priming cocks into the cylinders, also into the exhaust-valve guides. Five or 10 minutes after this is done, the engine should be restarted and run 3 or 4 minutes before stopping. This will insure an easy start next morning. It will also loosen up the carbon deposit upon the pistons and exhaust-valve stems.

Irregularities in Starting Engine.—Failure to start the engine might be caused by the throttle being open too wide. In cold weather the carbureter should be primed well; and in warm weather, should be primed slightly. After the engine has once started, it should not be primed too much before restarting. The use of high-test gasoline for priming helps starting greatly but should be used with caution, taking care not to overprime, allowing gas to run down into crank case, which might cause considerable damage.

If repeated attempts to start engine as above directed do not succeed, it is advisable to inspect the spark plugs. Five out of ten cases of ignition trouble is due to dirty or incorrectly spaced spark plugs. The correct spacing is 0.015 inch. All should be exactly uniform. Be sure points are clean. Dip tooth brush in gasoline and brush points. Examine the wire leads to be sure they are each in their proper place (see Fig. 69).

If, after a test, it is found that there is no current delivered at the spark plugs, the magneto should be looked into according to the instruction book issued by the magneto manufacturers, and if not easily remedied, they should be sent to the factory representative for repairs.

If the ignition system is found to be satisfactory, the trouble must then be in the fuel supply, or the fuel itself. The carbureter float may be full of gasoline, allowing the float chamber to flood, which will also happen if the needle valve does not work free, or some obstruction gets in between seat and

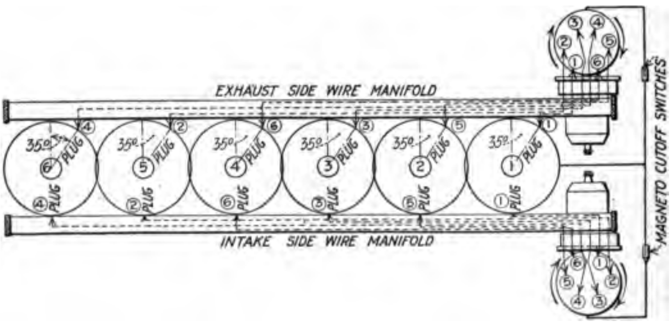


Fig. 69.—Ignition wiring.

valve. The supply pipe might be clogged partially or altogether. If force feed is used, the air pressure has to be tested, as there might be an air leak, or the air-pressure gage might register a certain amount of air which is not in the tank. There is a possibility that the jets in the carbureter are stopped up. If this is the case, do not attempt to clean the jets with any sharp instrument. If this is done, it might change the opening in the jets, thus spoiling the adjustment. Jets and nozzles should be blown out with air or steam.

An open intake or exhaust valve, which might have become sluggish or stuck from carbon, might cause trouble. Be sure to remedy this at once by using a little coal oil or kerosene on same, working the valve by hand until it becomes free. We recommend using graphite on valve stems mixed with oil to guard against sticking or undue wear.

Decrease in Engine Efficiency.—After the engine has been used continuously in hard service for a certain length of time, it may decrease in its r.p.m. There are different causes for this. In the magneto housing distributor, the carbon brush running between the distributing points will leave a deposit. This fine dust will partially shorten the magneto, causing the motor to pre-fire or run roughly.

The distributor block should be removed and wiped out as previously suggested.

Carbon in the cylinders and on top of the pistons will also decrease the r.p.m., as well as cause pre-ignition, hammering, and loss of compression. If motor oils are used as recommended, this trouble will be delayed for the longest possible time.

Natural wearing of surfaces must be taken into consideration, and for this reason our company recommends the disassembling, inspection, and cleaning of engine within a reasonable length of time.

Disassembling.—This should only be undertaken by a fairly competent and careful mechanic who has thoroughly acquainted himself with this type engine.

A table or bench should be provided to receive the parts for inspection that are taken from the motor, cleaned thoroughly in distillate, and dried. It is recommended to use Hall-Scott disassembling stands, special tools and shim boards, which will make the work more thorough, rapid and efficient.

The engine should be disassembled as follows: Remove lower crank case, turn crankshaft around until piston in No. 1 cylinder is on top dead center, on exhaust stroke (that is, shortly before the exhaust valve closes and intake valve opens). This will bring all marks referred to in line (see Figs. 70 and 71).

Leaving crankshaft in this position, take off camshaft housing cover and make sure that mark on camshaft gear, and line in bottom of camshaft gear housing, are in line. If this is the case, the camshaft housing can be removed as follows: Disconnect overflow oil pipe leading from camshaft housing to magneto gear housing box. Remove the four ¼-inch nuts holding stuffing box to lower portion of camshaft housing, sliding this down the lower shaft slightly. Remove the twenty-four 5⁄16-inch nuts from camshaft housing hold-down studs. The camshaft housing with camshaft, etc., is ready to be removed. This should be lifted upward, being careful not to cramp same upon the cylinder camshaft housing hold-down studs. The wire manifolds (note they are right and left) with oil and water pipes, should be removed. By removing nuts and washers, the cylinders can easily be removed.

All engines above 183 have been marked according to above instructions.

If it is only required to grind the valves, remove carbon and inspect piston rings. It is preferable by far to turn the engine upside down, remove the lower crank case, detach each connecting-rod bearing from its rod after which the pistons and rods can be removed from their cylinders.

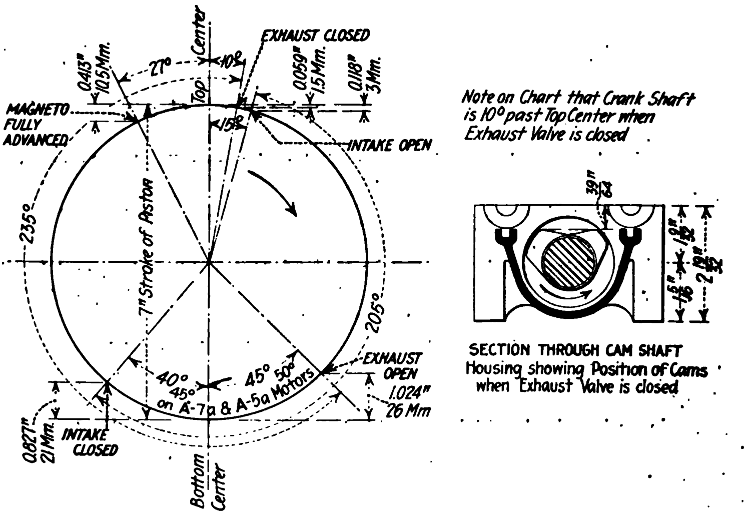


FIG. 70 —Diagram for disassembling.

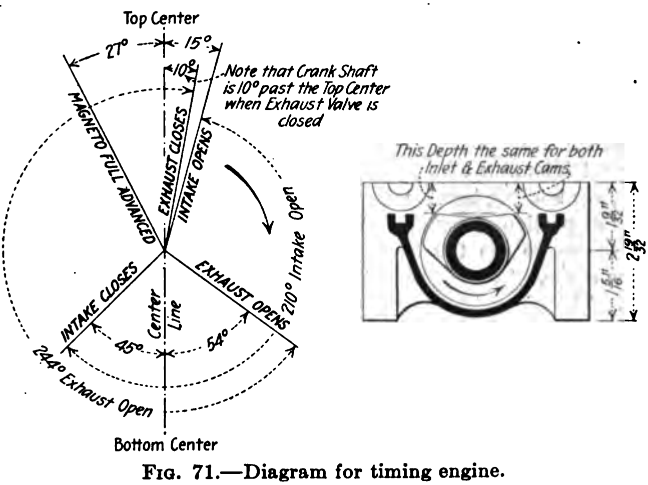


FIG. 71.—Diagram for timing engine.

This allows free access to valves, cylinders, pistons, rings, etc.

If it is necessary to remove the camshaft housing and the timing is wished to be maintained, proceed in the following manner:

Set the crankshaft as described above. This will bring two center punch marks on vertical shaft flanges into view; disconnect these two flanges, and remove camshaft housing.

Grind Valves.—The valves are of tungsten steel and will not warp or pit except in unusual cases. The valve seats, however, may collect a carbon deposit which will prevent the valve from seating properly. When this occurs, the valves should be removed and the seats ground, using a mixture of oil and powdered glass, or some prepared valve grinding paste.

To grind the valve seats, place a bar, having two holes through same, down over the two camshaft housing hold-down studs opposite the valve to be removed. Replace the two nuts. Remove the cotter pin in valve stem under the valve-spring cup. Using a special Hall-Scott valve tool which can be slipped under the bar, it will be easy to force the valve cup and spring down so the small key can be readily removed. This will allow the removal of both valve spring and cup. Take out the valve and clean it thoroughly, also noting whether or not the stem is clean, or otherwise in good condition. Replace the valve and grind by rotating it back and forth with a screw-driver, the grinding paste being between the valve and the seat. Care should be taken to raise the valve from its seat frequently while grinding. This prevents grinding a groove in the seat.

It is essential after the valves are ground to clean the entire cylinder with gasoline, wiping same with a soft clean rag, making sure all the grinding paste has been removed.

The side of the cylinder walls should be oiled with clean oil before cylinders are slipped over pistons into place.

Cleaning Pistons.—When slipping off the cylinders, care should be taken to steady the pistons so they will not fall over after cylinder is removed, which would result either in cracking the lower edge of the piston, which is extremely thin, or distort its shape. It is advisable to bend an iron band to insert inside each piston immediately after removing cylinder. These bands can be purchased at a nominal cost.

To remove the piston rings three or four strips of $\frac{1}{32}$-inch spring steel should be used. These should be slipped around the ring until it is entirely free of the groove, after which it can be slid off quite readily. Each ring has to be replaced in its original groove (see marks on inside surface of ring) as they are all differently spaced to allow for the different heat expansions.

Clean slots by scraping, taking care not to scratch the metal. Use cloth, moistened with gasoline, to clean the surfaces after carbon is removed.

If there are any bright spots on the outside walls of the piston, it shows an undue amount of friction is taking place at that point. A very fine file can be used to touch up these spots.

In reassembling the rings in their respective grooves, they should be free to move around each groove without binding at any place. Oil the pistons, rings, and grooves before assembling in cylinders.

Removing Wristpins.—We do not advise the disassembling of the piston from the connecting rod unless absolutely necessary. When this operation is necessary, remove the set screw holding wristpin in position. Use a small piece of hardwood, driving the wristpin by light tapping of a hammer on opposite end from the set screw. This pin should be replaced from the same end, namely, side of piston having set-screw hole in piston-pin boss.

If it is necessary to fit new bushings in connecting rod, the wristpin should be pushed into place by hand without excessive binding at any point.

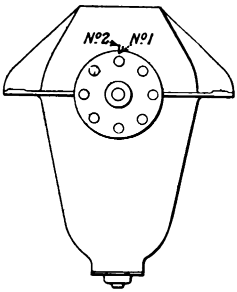


Fig. 72.—Reassembling engine.

A check upon whether or not the wristpin and piston are in line is to move the connecting rod, by hand, sideways upon the crankshaft after the piston and cylinder have been assembled. There should be no binding if the surfaces are oiled and the assembly is properly made.

A-7a and A-5a engines are equipped with aluminum pistons. It is necessary to heat the piston with a torch which will allow easy removal and replacement of wristpin.

Reassembling Engine.—*It is most essential that all parts are thoroughly cleaned with gasoline and wiped dry with a soft, clean rag before being replaced upon the engine.*

Bring mark No. 1, on crankshaft flange (see Fig. 72), using a square, dead true in line with mark on crank-case body, No. 2, which is stamped T. C. (top center), of crankpin in No. 1 and 6 cylinders. After this, crankshaft should not be moved until the entire engine is assembled.

The vertical shaft should next be assembled. It being exceedingly difficult to see the mark on the lowest set of gears, a mark No. 3 is provided on both vertical-shaft flanges. These must be set in exact dead center position as shown in Fig. 73.

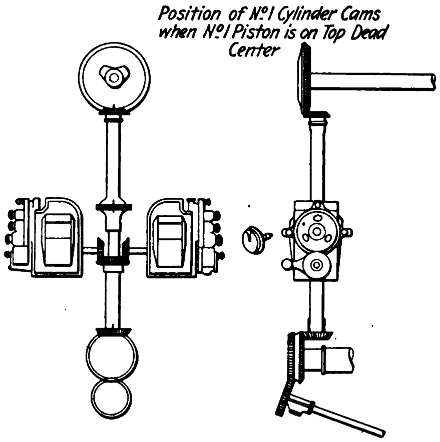


FIG. 73.—Assembling vertical shaft.

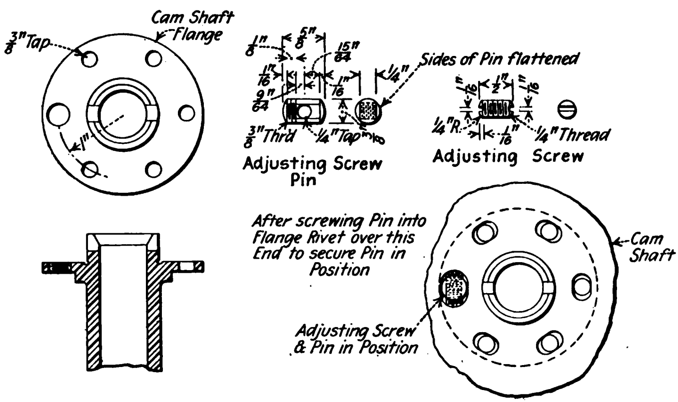


FIG. 74.—Lining up camshaft gear.

The camshaft with housing can now be slipped into place. Notice mark No. 4 on camshaft gear, which should line up with mark in the bottom of camshaft gear housing (see Fig. 74).

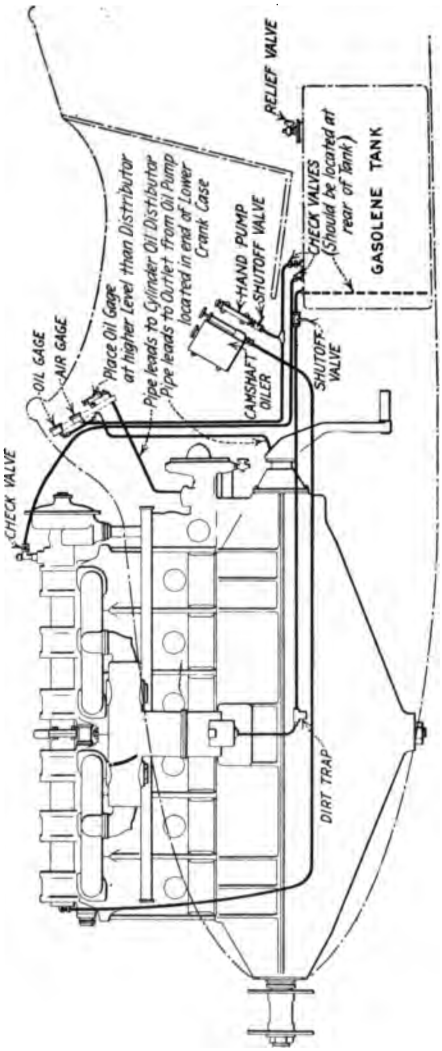


FIG. 75.—Hall-Scott engine in airplane

Care should be taken at this stage to look at the cams for No. 1 cylinder, to determine that they are in the position illustrated in Fig. 73. If this is not correctly placed, some mistake has been made and has to be found before going further.

After everything checks up satisfactorily, the magnetos should be installed. Take magneto marked at the base, and gear with letter "L" (meaning left-hand), remove distributor, turn magneto shaft until hole with red ring lines up with red mark on magneto body, which can be seen as hole passes mark. Insert magneto "L" left-hand side and magneto "R" on right-hand side. After gears are in mesh, be certain the holes in gears are directly in line with red marks on magneto body.

Care should be taken to ascertain both magnetos synchronize, or, in other words, break perfectly at the same time.

Fitting New Cylinders.—It is very important that extreme care be taken in replacement of cylinders upon engines, with new cylinders.

In fitting a new cylinder, the hold-down stud nuts should be loosened upon all cylinders on the engine and the new cylinder fitted in its place without binding.

It may be necessary to file out the hold-down stud bosses a trifle in order that a new cylinder will line up all around and make a perfect fit with the crank case.

In case the hold-down stud boss does not line up horizontally with the adjoining cylinder hold-down stud boss, it should be brought down to position with a facing cutter.

The hold-down stud nuts must be tightened evenly all around and cannot be pulled down with too much pressure or it will result in breaking the boss away from the ⅛-inch cylinder wall.

Fig. 26 showed the thrust bearing and propeller fitting and Fig. 75 the mounting of the engine in a tractor fuselage.

SECTION X

SUGGESTIONS AS TO THE STURTEVANT AIRPLANE ENGINE

Do not change engine adjustments as the engines are in perfect running condition when leaving the factory and all adjustments are correct.

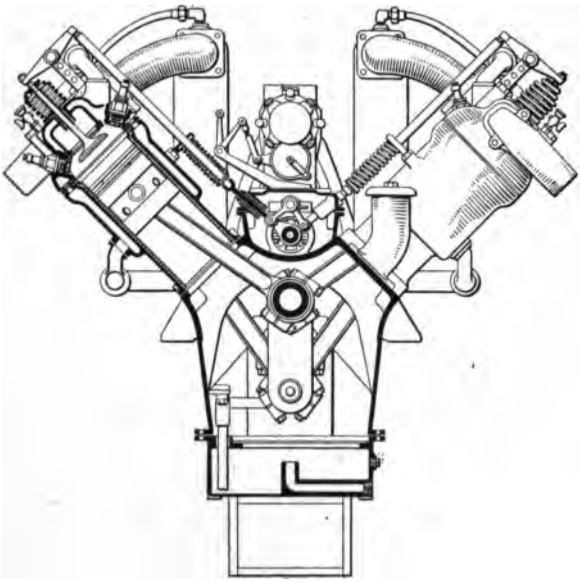


FIG. 76.—End view of Sturtevant engine.

In event of any difficulty arising in connection with the operation of the engine, be sure to investigate all possible sources of trouble before attempting to reset the magnetos, valves, carbure-

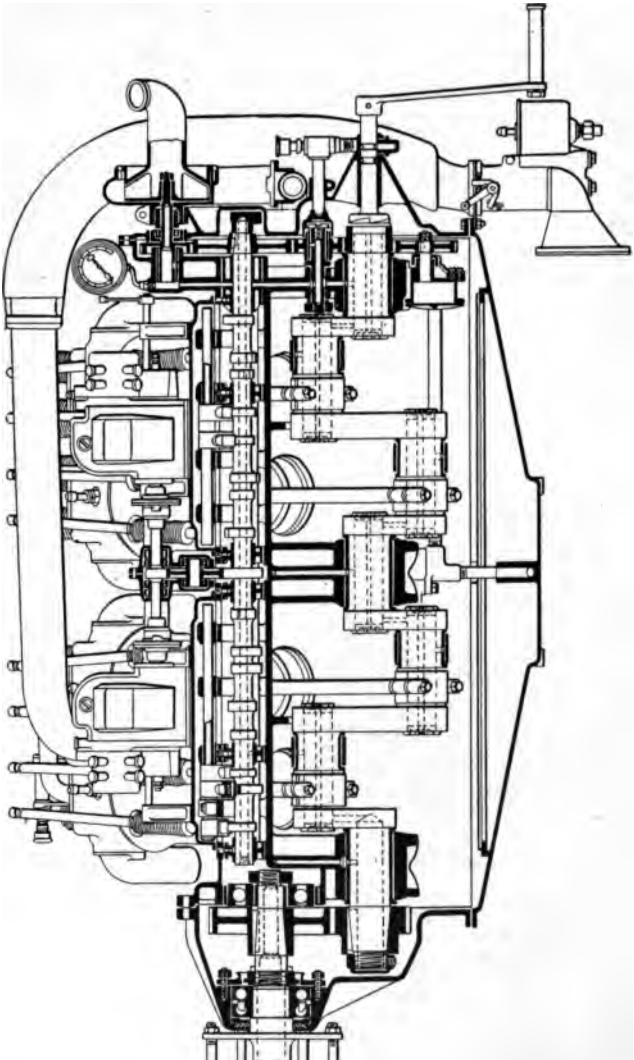


FIG. 77.—Longitudinal section of Sturtevant engine.

ter, etc. After the trouble has been located be sure that you understand thoroughly how to correct it before proceeding. Study Figs. 76 and 77 to become familiar with the construction of this type of engine.

Unpacking the Engine

All engines, when ready for shipment, are carefully packed in strong waterproof cases of special design, enabling the engines to be removed with little difficulty.

First.—Before attempting to remove engine, see that the case rests firmly on the skids.

Second.—Remove the large cover on the top of the case. This is held in place with screws.

Third.—Remove the covering from the engine, which is held in place with string.

Fourth.—Remove four bolts holding engine bed members to cross timbers at each end.

Fifth.—The engine is now ready to lift out of the box. This should be done very carefully and preferably by means of a chain hoist or block and tackle.

Sixth.—The engine-bed members may next be removed if not desired for convenience in further handling the engine. The six bolts used to attach the engine to these members are designed for holding the engine to its bed in the plane, are of alloy steel and should be saved.

Seventh.—Spare parts are frequently shipped with the engines, being packed in wooden boxes which are held in place in the case of screws, which are inserted from the outside. Obviously these parts should be removed before attempting to take engine out of the case.

Installing the Engine

The successful operation of an airplane engine depends to a large degree upon its proper installation in the airplane fuselage, and as a result of experience we urge that the following points be observed closely.

Radiator

For best efficiency, the vertical height of the radiators should be kept down and face area obtained by increasing the width. The top header should be proportioned so as to distribute the water properly, to prevent its piling up or surging. At 2000 r.p.m. engine speed the pump circulates 80 gallons of water per minute.

The system is simplified if radiators are mounted above the level of the engine bed.

All radiator connections, water pipes, elbows, unions, etc., should be of large size, and in no case of less diameter than the water connections for the engine. Connection from engine to radiator should be the shortest possible and with the least number of bends.

Do not fill the radiator so that it will overflow. It is much better to have a part of the header space empty; otherwise when the engine is started up a great deal of the water may be lost through the overflow pipe.

Gasoline and Oil Tanks

The gasoline tanks, which may be of any shape or size desirable, should be located so that the bottom of the gravity tank will always be at least 8 inches above the level of the carbureter.

The oil tank may likewise be of any size, shape or capacity. However, it must be located so that its highest point will always be below the level of the sump of the engine at any angle which the airplane may assume in normal service.

Starting the Engine

First see that the engine is securely fastened down on the engine bed of the airplane. Then carefully examine the oil, gasoline and water-pipe connections and see that all are properly made and tight.

See that the gasoline tank is filled with gasoline of at least 63°Bé. and the lubricating oil tanks and sump with "A" Mobiloil or equivalent. Fill the reservoirs in the valve rocker pins on the top of the cylinders with the same oil as used in the sump. The cup ends into which the tappet rod fits should be filled with flaked graphite and grease mixed. Also fill tachometer joint grease cup with a good non-fluid grease and fill the radiator with pure filtered water.

If the engine has been standing for some time without running, it is well to squirt a little oil into the cylinders.

All spark plugs should be carefully examined to see that there are no broken porcelains. The porcelains are very easily cracked when unpacking the engine or during the process of installing same. Furthermore, after the engine has been run for a short time, oil will tend to deposit on the porcelains and in many instances causes the spark to short-circuit. Keep the spark plugs clean.

Standard engines are regularly furnished right-hand rotation unless otherwise ordered.

The rotation of the engine is determined when facing the water-pump end —that is, if the crankshaft rotates clockwise the engine is right-hand; if counter-clockwise, left-hand. On a right-hand engine the propeller turns clockwise when facing the propeller. This is true only when the propeller shaft is operated through a reduction gear. On a right-hand, direct-drive engine the propeller turns anti-clockwise as viewed from the propeller end of the engine.

To start the engine the switch should be placed in the off position marked "Stop." The spark should be fully retarded by pulling up the magneto levers against the tension of the spring. The throttle should be opened a little way only, because in this manner a strong suction is induced in the priming hole at the edge of the butterfly which raises the gasoline and effectively primes the cylinders. The throttle should not be more than ⅛ inch from the stop.

All of the cylinders should now be primed by squirting in a few drops of gasoline. Do not use too much gasoline as it will destroy the film of lubricating oil on the cylinder walls. This would result in the pistons seizing. *Do not under any circumstances prime the engine with ether or other chemicals.*

See that the gasoline is turned on at the tank and then proceed to turn the engine over until the propeller or starting handle is in a convenient cranking position.

Now turn the switch to the position marked "Run" and give the propeller a quick turn downward or the starting handle a quick turn in the direction of rotation. If the engine fails to start, turn the switch to position marked "Stop" and then turn the engine over until the propeller or starting handle is again in a convenient cranking position. If it does not start after two or three attempts it should be primed again. It may start and run for a few explosions and then backfire and stop. This is more likely to happen in cold weather and can usually be prevented by placing a piece of paper or some similar object over the carbureter air inlet for a few seconds until the engine commences to get the proper mixture.

Persistent cranking is usually of no avail. If the engine does not start readily, bring the switch to the position "Stop" and look for the reason and correct the trouble instead of trying to make the engine start by continual cranking.

It is most likely that the cylinders are not getting gas and need further priming as the carbureter is large for the size of the cylinders in order to obtain maximum power at high speed, and at cranking speeds it is sometimes difficult to get sufficient suction to start the engine.

In cranking the engine use care on account of the liability of a back kick.

Starting Engine with Christensen Air Starter

First.—See that there is at least 175 pounds of air in the air tank.

Second.—Turn on the main gasoline supply and see that the shutoff cock of the gasoline pipe leading from the main gasoline line to the starter carbureter is turned on (see Fig. 81).

It is necessary to use the gasoline mixture only when first starting the engine and in extremely cold weather. When the engine is warm the gasoline supply to the starter carbureter can be shut off and the engine started on air alone.

Third.—Turn the ignition switch handle to the position marked "Run."

Fourth.—Turn the handle of the selector or control valve to the position marked "S." Then press the central button on the control valve, thereby allowing compressed air to flow from the starter tank to the carbureter mechanism of the air starter and finally to the distributor mechanism. The mixture of air and gasoline passes through the check valve into the cylinders.

The compressed gasoline mixture explodes as in the regular hand-cranking operation of the engine.

After the engine starts, turn switch on the control valve to the "Neutral position" marked "N."

To keep compressed air in reservoir indefinitely, close stop valve to "N." Handle is detachable to prevent tampering with the apparatus by unauthorized persons.

To start compressor, move handle to position "P" and press button. To stop compressor, move handle quickly to position "N."

To inflate tires, start compressor, then move handle slowly to "N" and attach tire hose to nozzle. Press button and air will flow from the tank into the tire, until button is released.

Running the Engine

Immediately after the engine starts, the throttle should be opened about one-half and the spark advanced about one-quarter, allowing the engine to operate at half speed for a few moments until it becomes warm. Make sure that the water is circulating through the pipes between engine and radiators, either by noting the temperature as indicated by the thermometer or by placing the hand on one of the pipes. The spark should be fully advanced before further opening the throttle.

Oil pressure should be registered by the pressure gage immediately the engine starts. If no pressure is indicated, the engine should be stopped immediately (see Lubrication). Oil may not commence to pass through the oil sight-glass until the engine has been running a few minutes or so, but this is nothing to be alarmed about, since the engine can be operated safely for a few minutes without the oil-supply pump working.

Stopping the Engine

Close the throttle and retard the spark about halfway, allowing the engine to idle for a few moments. Then turn the switch to position marked "Stop." If the engine continues to run, due to its being hot, first close the throttle and then quickly open it. This will cause a very lean mixture to be drawn into the cylinders and will tend to cause the engine to stop. Do not allow engine to continue to run after magnetos are short-circuited. The gasoline should be shut off if necessary.

Lubrication

Lubrication is of the complete forced circulating system, the oil being supplied to the principal bearings under pressure by a rotary pump of the gear type which is located under the crankshaft bearing on the timing-gear end and operated by a gear from the crankshaft. The oil sump forms a reservoir from which the oil pump draws its supply through the oil suction pipe, Fig. 78. Oil is delivered through a vertical passage integral with the end of the base to the oil duct which connects the three crankshaft bearings.

From the timing-gear end of this duct the oil passes through oil holes drilled in the end of the base up to the idler gear and camshaft bearing and is distributed through the hollow camshaft to each of the main camshaft bearings. It also passes around a groove in the camshaft bearing and is delivered to the water pump shaft bearing directly above, at which point the oil-pressure gage is located. From the crankshaft bearing the oil enters the hollow crankshaft and passes through a hole in the crankarm to the big ends of the connecting rods of cylinders.

From the center and propeller end of the oil duct the oil passes down through drilled holes in the base to the crankshaft bearings where it enters the hollow shaft. In the case of the center bearing the oil passes through holes in the two adjoining crankarms and lubricates the big ends of the connecting rods of cylinders, while the oil from the remaining rods is received from the propeller-end crankshaft bearing. The cylinder walls, pistons and wristpin bushings are lubricated by the oil which is thrown off from the crankshaft after passing through the bearings, and this oil subsequently returns to the oil sump through the filter screen and is recirculated by the pump.

The oil supply pump is located on the outside of the engine on the timing-gear case cover underneath the water pump. This is of the plunger spring return type operated by a cam on the end of the camshaft. It has one outlet ball valve and the inlet is through a port uncovered by the plunger. This pump takes oil from the auxiliary oil tank and delivers it into the

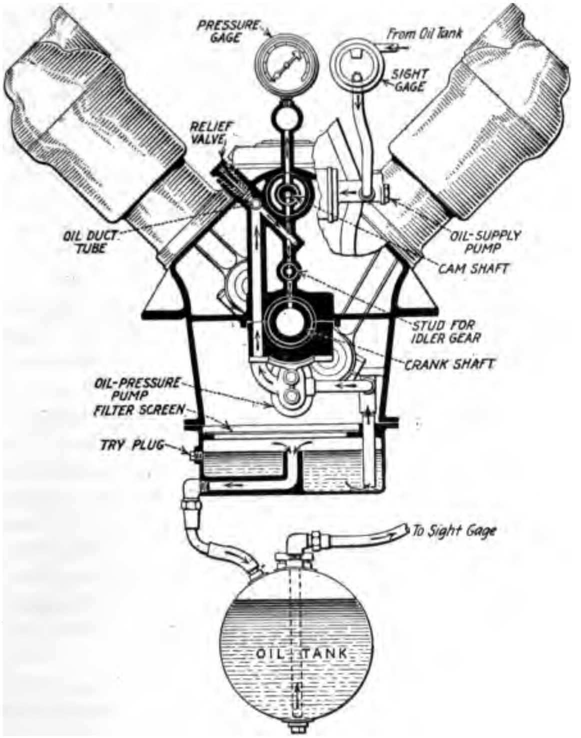


Fig. 78.—Oiling system.

sump at a faster rate than it is used by the engine. The excess oil overflows from the sump to the oil tank. A sight glass is provided in the line from the oil tank to the oil-supply pump to indicate that this is working properly.

The object of this arrangement is to supply a constant amount of cool oil to the reservoir in the sump from which the oil-pressure pump draws its supply and to maintain a constant amount in the sump for the pressure pump to circulate.

The pressure at which the pressure pump is delivering the oil to the bearings is recorded on a gage which indicates that the oiling system is working. This gage should be constantly in view of the operator and may be either attached to the base in front of the water pump or piped from here to a point on the instrument board. The pressure recorded on this gage will vary considerably and cannot be controlled perfectly, but should be held within the maximum capacity of the gage and a minimum of 10 pounds. If upon starting or at any time while the motor is running the pressure should fall to zero the motor must be stopped immediately.

The maximum pressure is controlled by a relief valve which is provided for the purpose of preventing an excess pressure in the system when the oil is cold and will not pass through the bearings freely. This valve should be adjusted to prevent the pressure from exceeding the maximum capacity of the gage. The relief-valve guide is unscrewed from the base to lower the pressure and screwed into the base to increase the pressure. It is adjusted at the factory and should not need further attention unless the grade of oil is changed or the engine is used in very cold weather. If a very heavy oil is used in cold weather it may be found that the relief valve will not have a sufficient capacity to hold the pressure within the limit of the gage. If a light oil is used in warm weather the pressure may not reach the maximum even upon starting the engine.

When the oil becomes warm after the engine has operated a short time the pressure in the system will drop considerably, due to the fact that all the oil delivered by the pump will pass through the bearings with less pressure on account of its lower viscosity when hot. This normal running pressure is not affected by the adjustment of the relief valve as the relief valve is in the nature of a safety valve and when the pressure drops below the point at which the relief valve is set, it is an indication that all the oil is passing through the bearings.

The normal pressure when the engine is operating at full speed should not be less than 10 pounds, and if it falls below this the engine should be stopped.

If it drops suddenly from a normal pressure of 30 to 40 pounds to less than 10 pounds it is probably due to exhausting of the oil supply or some serious leak which has developed in the system or the relief valve may have become unscrewed.

The gasket between the oil pressure pump and the bearing cap is a point where leakage may occur, due to the deterioration or breakage of the gasket.

If the pressure gradually falls over a considerable period of time it is probably due to worn bearings allowing the oil to pass through them more freely. Fresh oil will improve this condition and fresh oil of a heavier grade will improve it considerably.

If no oil pressure is shown upon starting the engine it is an indication that the oil-pressure pump is not working. This may be caused by an air leak in the oil suction pipe leading from the sump to the pump or to the pump becoming worn to such an extent that it will not lift the oil from the sump.

The condition of the bearings has a marked effect upon the oil pressure. If the bearings are tight the normal pressure will be high, while if the bearings are loose the normal pressure will be low. A combination of loose bearings and thin oil will allow the pressure to drop to a low point when the engine becomes hot. Under these circumstances, the cylinders will receive excess oil, although the pressure in the system will be low because more oil is passing through the bearings and being thrown off by the crankshaft. If, however, the crankshaft bearings are adjusted too tight, especially the connecting-rod big ends, the oil pump will maintain a high pressure in the system, but the cylinders will receive insufficient lubrication. In fact the consistency of the oil and the condition of the bearings have to be such that the cylinders will receive proper lubrication.

A sight-glass indicates whether the oil-supply pump is working properly. Oil may not begin to pass through this glass immediately after starting the engine, as it takes about a minute for the pipe to fill. If, however, the oil does not commence to pass through the glass within a few minutes after starting, the cause should be investigated. If the oil ceases to pass through the sight-glass while running, the amount of oil in the sump is sufficient to allow the engine to be run safely for 1 hour, although it is not desirable to operate the engine under these conditions unless absolutely necessary.

The most likely causes for failure of the oil-supply pump are as follows:

1. No oil in the auxiliary oil tank.

2. Air leak in pipe from oil tank to sight-gage. This can be determined by careful examination, and if the pipe is not cracked the union connection may be loose or the glass in the oil gage not air-tight.

3. The outlet valve may leak. This can be inspected by removing the small plug on the top of the pump. If the cause of the leak is not apparent it will be necessary to remove the pump from the gear case in order to let the valve drop out of its chamber. Some foreign particle in the oil may prevent it from seating or the valve may need to be reseated, which is readily accomplished with a punch and a few blows of a very light hammer.

4. The plunger may stick, due to standing for some time and the oil becoming congealed. It is operated in one direction by a spring. The pump should be removed, and if the plunger does not operate freely it should be cleaned and lubricated with fresh oil.

A high-grade gas-engine cylinder oil such as "Mobiloil A," will be found preferable in ordinary weather. Both the oil sump and the oil tank should be drained frequently and refilled with fresh oil. It is not necessary to do this every time that the tank is filled, but it is well to do it after every 5 hours' operation of the motor. If gasoline is used to clean out the sump and the tank the motor must not be operated until it has been all drained out and fresh oil put in.

Carbureter

The carbureter is located on the timing-gear end of the engine beneath the level of the engine base and connected to the cylinders by means of water-jacketed aluminum intake manifolds. It is of the duplex type, having one float chamber and two barrels, each supplying one group of four cylinders. It operates upon the Zenith principle and each barrel contains four variables which are used in setting the instrument to properly proportion the mixture. These are the choke, the jet, the compensator, and the priming tube.

The choke regulates the flow of air around the jet. The jet regulates the mixture principally at high speed. The compensator regulates the mixture principally at medium speed. The priming tube regulates the mixture at very slow speed, and assists in starting. Only one external adjustment is provided, the slow-speed screw, which affects the priming tube. This controls the air inlet to the priming tube and screwing it in gives a richer mixture for starting and idling, and unscrewing it gives a rarer mixture. The size of the priming tube, therefore, does not have to be exact as its delivery can be regulated.

The choke is of a size determined by us at the factory and need never be changed or removed from the carbureter. The jet and compensator are of a size determined at the factory and should not require alteration except under extraordinary circumstances. The most likely carbureter trouble will be that the jets become clogged with some foreign matter. The gasoline also has a tendency to form a deposit in the drilled passages through the aluminum body and these will want to be cleaned out from time to time by removing the screws. If, however, the jets and all passages in the carbureter are clean and the mixture does not seem to be corrected, which may be the case due to climate or fuel, the adjustments can be altered as follows:

If the mixture appears to be too rich at slow speeds, which is detected by black smoke in the exhaust, uneven running and loading which prevents the engine speeding up quickly when the throttle is opened, this can be corrected by unscrewing the slow-speed screw.

If the mixture is too rare at slow speeds, which will be detected by the engine stopping when throttled down low or running unevenly and vibrating at low throttle, this can be corrected by screwing in the slow-speed screw.

If the mixture is too rich at a point between closed throttle and half throttle, shown by black smoke and uneven running, this can be corrected by reducing the size of the compensator which will also make the mixture slightly rarer at full throttle.

If the mixture is too rare at any point from closed throttle to half throttle, shown by popping or backfiring in the carbureter when opened up quickly, especially in cold weather or when the engine is first started before receiving hot air, this can be corrected by increasing the size of the compensator which will also slightly enrichen the mixture at full throttle.

If the mixture is too rich from half to full throttle, shown by black smoke, the jet should be decreased, and if too rare, increased. The sizes of the nozzles are marked in millimeters, and in the event of not having extra jets on hand they can be redrilled.

The most likely trouble will be that the mixture is too rare upon starting up on a cold day, and popping or backfiring will occur at half throttle. This will not continue after the motor has been run a few minutes and the inlet pipes become warm. To facilitate starting and running the motor in cold weather for the first few minutes a piece of paper or sheet metal, or even one's hand, can be held over the air inlet to partially close this opening and increase the vaccum on the jets.

If the float chamber overflows when the gasoline is turned on, remove the screw top over the needle valve and press down the needle-valve stem and twist at the same time to improve the valve seat. If this does not prevent the trouble and the carbureter continually overflows when the engine is not running it will have to be removed and the valve stem ground into its seat. It is possible that the float may develop a leak which will prevent it from rising in the float chamber and closing the needle valve.

The carbureter is adjusted at the factory to operate using motor gasoline, 63°Bé test. *Ether, picric acid or other chemicals should never under any circumstances be used, either in the carbureter or for priming the engine.*

Ignition

Two high-tension Splitdorf magnetos, type Dixie Model 81, are placed face to face between the two groups of cylinders. They are operated by the shaft through an intermediate gear from the camshaft and turned at crankshaft speed. The two magnetos turn in opposite directions, their direction of rotation being taken when viewed from the driving end, this being marked by an arrow. The one turning clockwise is located on the propeller end of the engine and the one turning anti-clockwise is located on the timing-gear end of the engine.

Care of the "Dixie 81"

The bearings of the magneto are provided with oil cups, and a few drops of oil after every 10 hours' operation are sufficient. The breaker lever should be lubricated with a drop of light oil to be applied with a toothpick.

The proper distance between the platinum points when separated should not exceed 0.020 or 1/50 inch. A gage of the proper size is attached to the screw-driver furnished with the Dixie. The platinum contacts should be kept clean and properly adjusted. Should the contacts become pitted, a fine file should be used to smooth them in order to permit them to come into perfect contact.

The distributor block should be removed occasionally and inspected for an accumulation of carbon dust. The inside of the distributor block should be cleaned with a cloth moistened with gasoline and then wiped dry with a clean cloth. Dust distributor in talc or soapstone. When replacing the block care must be exercised in pushing the carbon brushes into the socket.

The magneto should not be tested unless it is completely assembled, that is, with the breaker box, distributer cover and wires in position. Whenever the wires leading from magneto to spark plugs are taken off, observe that they are correctly replaced.

Do not pull out the carbon brushes in the distributor because you think there is not enough tension on the small springs.

In order to obtain the most efficient results with the Dixie magneto, the normal setting of the spark plug joints should not exceed 0.025 inch and it is advisable to have the gap just right before a spark plug is inserted into the cylinder.

Faulty ignition may be due to various causes, and a careful inspection should be made to ascertain whether the spark plugs or magneto requires attention. It may be pointed out that in general when only one cylinder misses the fault is almost invariably in the spark plug.

The more common defects of spark plugs are as follows:

1. Short-circuit at the spark gap is due to small metallic beads which are melted by the heat of the intense spark and form a conducting connection between the electrodes. This defect is easily ascertained and may be remedied by removing the metallic bead.

2. Cracked or broken porcelain insulation about center electrode. Broken porcelains must be replaced.

3. Too wide a gap between the electrodes. The normal width of a gap is 0.025 inch.

4. Fouling of the plug. If fouling should occur the parts exposed to the burning gases may be cleaned readily by removing the plugs from the cylinder and cleaning with gasoline.

The spark-plug cables must be tested and special attention should be paid to ascertaining that the insulation is not injured in any way. The metal terminals of the cables must not come into contact with any metal parts of the magneto, except the proper binding nuts. If cables and plugs are in good condition and yet the ignition works irregularly, the defect may be in the magneto.

A simple test for the magneto is to disconnect all wires and remove the magneto from the engine. Take a piece of insulated wire about 6 inches long and fasten one end to the grounding terminal. Next remove the eight thumb nuts from the distributor. Now hold the other end of the wire previously mentioned about 1/8 inch from each of the terminals on the distributor consecutively, and while rotating the magneto shaft rapidly by hand, note if any sparks can be seen between the wire and the terminals. If sparks are seen, it is an indication that the magneto is probably in proper condition.

If no sparks are observed, the interrupter housing cover should be taken off by moving the terminal nut. Now look at the platinum points and see whether they are in contact when the steel cam is not acting on the magneto interrupter lever; also whether they separate the correct distance of 0.020 or 1/50 inch when the interrupter lever is resting on one of the points of the steel cam. Otherwise the distance must be adjusted by means of platinum screw. The platinum contacts must be examined and any oil and dirt removed; in case the contacts are uneven (but only then) they must be smoothed with a fine flat file. If after continued use the platinum contacts are completely worn down the two platinum screws must be renewed.

If ignition fails suddenly, there may be a short-circuit in the cable connected to the grounding terminal which serves for switching off the ignition. This may be ascertained by disconnecting the cable from the terminal. It is also advisable to examine the distributor carbon brushes which may be done by removing distributor cover.

It is to be noted especially that the magneto interrupter lever moves freely.

If the examination so far has not led to the discovery of the defect and it is absolutely impossible to start the engine, the setting of the magneto should be verified and if found to be correct, the magneto should be returned to the Splitdorf Electrical Co., Newark, N. J., or its nearest official representative.

If it be necessary to remove the magnetos from the engine and no other part is disturbed, they can readily be replaced if certain precautions are observed. Turn engine to firing point No. 1 cylinder. Remove the distributor block and note position of the carbon brushes of the distributor rotor. The screws holding the magneto in place can then be removed and the magneto lifted from the engine. The engine must not be turned until the magnetos are replaced, but the magnetos can be turned if they are replaced with the carbon brushes of the distributor rotor in the same location.

If it is necessary to remove the magneto drive shaft and gear housing from the base, this cannot be replaced with the same setting, as the gears cannot be marked and consequently it is necessary to retime the magnetos. When these are in the most advanced position, with the timing levers down against the stop on each instrument, the sparks should occur in the cylinders

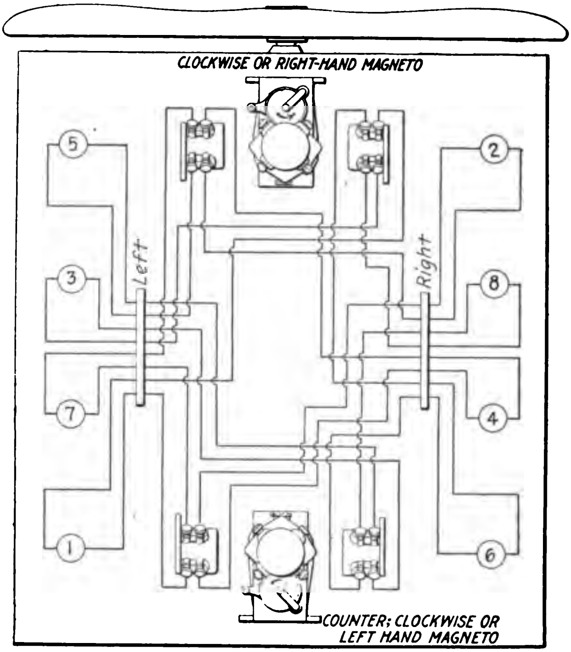


FIG. 79.—Wiring diagram for left hand magneto.

28 degrees before the piston reaches the top center on the firing stroke. This position of the piston may be secured by inserting a wire through the priming cup and locating the piston head ⅜ inch from the top center. The piston of No. 1 cylinder should be placed in this position and the magnetos should be fully advanced by pushing the timing lever down against the stop. The bolts should be removed from the adjustable coupling and

the magneto coupling. The magnetos should then be turned until the contact-breaker breaks and the carbon brush on the distributor rotor is in contact with No. 1 on the distributor case. The bolts should then be put through the corresponding holes in the couplings which come the nearest to this adjustment, keeping on the advanced side rather than the retarded.

This leaves both magnetos adjusted to fire No. 1 cylinder. Note that the cylinders on both the right and left sides fire in the order 1, 3, 4, 2, as viewed from the timing-gear end. By referring to the wiring diagrams, Figs. 79 and

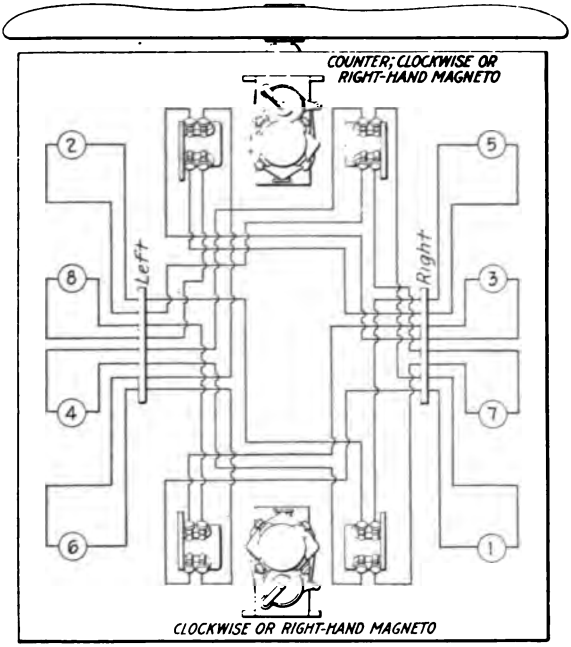


FIG. 80.—Wiring for right hand magneto.

80, it will be seen that the cylinders are numbered according to the order in which they fire. The letters "R" and "L" on the magneto distributor covers refer to the rotation of the magnetos only and not to the cylinders. That is, in a right-hand engine the counter-clockwise, or left-hand, magneto is located on the timing-gear end of the engine, and the clockwise or right-hand magneto on the propeller end of the engine. In a left-hand engine the rotations are obviously reversed.

All wires running from the propeller-end magneto should be connected to the spark plugs on the outside of the cylinder heads and all wires running from the other magneto should be connected to the plugs on the inside of the cylinder heads.

It may be found that the two adjustable couplings will not allow the two magnetos to be set with exactly the same advance. The minimum adjustment obtainable with these couplings is 4.3 degrees, so that one magneto may be as much as one-half of this ahead or back of the other when they are both fully advanced. This can be corrected by adjusting the yoke end turnbuckles which connect the two timing levers with the rod so that the contact-breakers of the two instruments will break the same.

Cooling

The water circulation through the cylinders and radiators is accomplished by a centrifugal pump which is located above the camshaft and driven from the camshaft gear. The pump shaft and its gear are carried in a bearing in the base which is supplied with oil under pressure. The thrust of the water-pump impeller is taken by a bronze pad in the rear gearcase cover. There is no bearing in the water-pump body, only a stuffing box to prevent leakage. The stuffing box may be tightened in the following manner. First, insert a spanner wrench or screw-driver in the slot on the stuffing-box nut and then turn nut away from the spring lock. To insert new packing the cover of the pump must first be removed. Then the nut is unscrewed from the water-pump shaft, and the impeller slipped off. The pump casing should then be removed and new packing inserted.

The cooling water is taken from the two radiator outlets into the pump through a forked inlet in the pump cover and discharged from the pump through water pipe into the cylinder water pipes. After passing through the cylinders it returns to the top of the radiator. It is possible for air locks to be formed in the cooling system after it has been drained. The upper half of the water pump may trap air so that the pump will not circulate the water upon starting the motor. To avoid this, open vent in the water pump and allow the air to be forced out of the upper half of the pump until the water fills its place.

A drain plug is provided on the water-pump pipe to drain the engine, and this removes all that is necessary to prevent damage from freezing, except that in the jacketed inlet pipes. The inlet pipes are each drained by removing separate plugs. Clean water should be used, and it is advisable to have a strainer in the funnel which is used for filling the system. The engine should not be operated persistently when the water boils, as the pump will cease to circulate owing to steam pockets which collect in the cylinders, and the cylinders will become overheated rapidly, while there may be water in the radiators.

Christensen Air Starter

The Christensen self-starter, while using compressed air primarily, is not a compressed-air starter in the sense that it employs the regular compression and fuel on which the engine is regularly operated.

The system comprises an apparatus whereby the compression stroke is positively and automatically furnished before the engine itself is in motion.

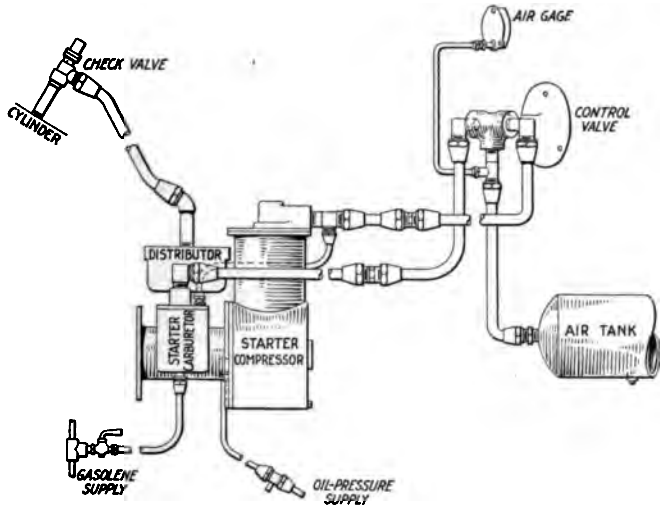


Fig. 81.—Christensen air starter.

This apparatus comprises an apparatus whereby the compression stroke is positively and automatically furnished before the engine itself is in motion.

This apparatus comprises the following essential parts (see Fig. 81):

1. Self-starter unit comprising air compressor, automatic carbureter, clutch for engaging and disengaging the compressor from the engine, so that the compressor is never in operation except when compressing air for restoring the pressure in the tank or for inflating tires.

2. An automatic distributor by which air is delivered to the cylinders in rotative firing position of the pistons.

3. An air tank for compressed air.
4. Selector or control valve and air-pressure gage.
5. Check valves which are arranged on cylinders.

The lubrication of the starter is completely and entirely automatic, a ¼-inch pipe being connected from the pressure system of the engine to the oil fitting at the back of the starter. Oil is constantly fed to the working parts of the starter, a level maintained in the compressor crank case and the excess oil is drained back into the engine crank case.

The carbureter of the self-starter is connected by means of ¼-inch brass tubing to a special tee and stop-cock. This tee is connected to the main gasoline line. The carbureter is provided with an automatic float which shuts off the gasoline as soon as it has reached a proper level.

Timing the Air Distributor

First, turn the engine until the piston of cylinder No. 1 is at top dead center. Remove the distributor cover and take out the piston directly under it. This will expose a double-nose cam which slides up and down on a square cam stud. This cam stud is screwed into the distributor shaft and locked up in position by a locknut, both right-hand threaded.

There are two rows of valve stems exposed in the center of the distributor body; one above the other. Turn the stud to such a position that when the cam is pushed down, the top cam nose, for forward rotation of engine, will just rub on the valve stem ready to open the valve.

When the cam stud is set in the proper position it should be locked there by turning down the locknut good and tight. Then again put in the cam, push the same down and note that the position is still correct. If locking down the nut has changed its position it must be loosened again and reset. You can also tell whether the valve is open or closed by putting on a pipe connection to the distributor and blowing into it. Turn the engine in the correct direction of rotation until the exhaust valve on No. 1 cylinder is just commencing to open; again push down the cam in contact with the valve and note if valve is still open. In this position the distributor valve should be closed so as not to allow the air to blow through the exhaust valve into the atmosphere, which would be wasteful and cause unnecessary loss of air.

The cam nose is so constructed that if set to properly open it will also close at the proper time. All the other cylinders being connected to the distributor in their firing order, and corresponding to the firing order of the engine, are of course correctly timed, it being only necessary to time No. 1 cylinder so as to get the correct openings.

The easiest way to adjust the cam stud is by use of socket wrenches, one to fit the $\frac{5}{16}$-inch hexagonal locknut and the other to fit the square cam stud. Pipe to the different cylinders in the order of firing as indicated by the diagram.

The tank may now be charged from an outside source by partly withdrawing the handle of the selector valve from the stem and turning the same around so that the heel of the handle will fit in the slot provided for it in the flange. This gives a direct line from the tank to the tire inflator nozzle. By coupling the hose to the nozzle the tank can be charged to any desired pressure. If this outside means is not at hand, then move the selector valve handle to the pumping position, then while the engine is running turn the tee handle on the starter unit about 90 degrees in clockwise direction or as far as it will go. Hold the same in this position for a minute or two until the pressure of the compressor will hold it there by itself, and allow the engine to run until the gage registers a pressure of about 100 pounds. Turn the handle back to the neutral position, whereupon you will hear a sniff of escaping air and the clutch will immediately disengage. Stop the engine and listen for air leaks. If everything is tight you may start the engine again. This time as you have air in the tank turn the control valve to the pump position and press the central button sharply, all the way down. This throws the clutch in automatically. Then pump to a pressure of say 150 to 175 pounds and again stop the engine. You are now ready to start by means of the starter.

Avoid using too high pressure in starting operation as it may collapse the float in the carbureter. This does not necessarily put the starter out of commission, as the gasoline supply can be shut off when the carbureter is full, ready for the next start. It can be used in this way until a new float is procured. If the pressure in the reservoir runs down overnight any appreciable amount it will show that there is a leak somewhere between the tank, air gage and selector valve, no other lines being under pressure excepting during starting period. A leaky pilot valve might be the cause. This valve is the center of the selector valve and held in place by a hexagonal nut directly at outer end of base.

By removing the nut you can draw out the pilot valve and put on a new gasket. Care should be taken that the pilot-valve disc is put in correctly and should not project beyond the ring more than a good $\frac{1}{64}$ inch. While the machine is not in operation, you can detect a leaky pilot valve by placing the selector valve handle at the neutral point, leaving it there for a short period and then suddenly turning it over to one side or the other. If you hear a sniff of escaping air, you may be sure that the pilot valve needs repairing. It sometimes happens that a leaky pilot valve causes the carbureter to overflow or even force gasoline back up into the distributor and out the vent hole provided in the distributor base. In repacking the pilot valve you will readily overcome this trouble.

Be sure that all joints are tight, the gasoline feed to the carbureter is open and that the timing is exactly as explained. A 1/32-inch advance or retard of the cam makes a great difference.

Valves

The water should be thoroughly drained out of the engine before attempting to remove the heads.

Next, disconnect the water-pipe hose connections between cylinders and remove the spark-plug cables from the spark plugs.

The inlet manifolds should be disconnected at the point where they are bolted on to the water-jacketed section of manifold, after which they can easily be re moved from the cylinders.

The cylinder head can be easily taken off by removing the six long holding-down bolts. Once the cylinder head has been removed, it is a simple matter to get at the valves for grinding and cleaning purposes.

In addition, the carbon on the piston heads can very easily be cleaned off by turning the engine over slowly and bringing each piston to the top center.

In removing the cylinder head use care not to injure or destroy the molded copper gasket which is placed between the cylinders and cylinder head.

In replacing the gasket it is advisable to coat both sides with a mixture of graphite and linseed oil, or with cup grease.

Valve Adjustment

The clearance between the valve stem and rocker lever is adjustable and should be 0.010 inch when engine is hot. When engine is cold clearance should be set to 0.020 inch. This clearance is easily adjustable by means of the screw in end of rocker. A locknut is provided on the adjusting screw so that once the proper setting is obtained it can be fastened securely.

When perfectly adjusted the valve timing should be as follows:

Valve Timing

Inlet valve opens 15 degrees before top center.
Inlet valve closes 45 degrees after lower center.
Exhaust valve opens 45 degrees before lower center.
Exhaust valve closes 10 degrees after top center.

Bearings

The bearings should be carefully scraped, in order to obtain a good surface all over so that a stiff bearing is obtained when the caps are bolted down hard on the shims. The caps should be removed and shims of $\frac{2}{1000}$ inch thickness should be inserted in each side in order to give the proper running fit for the bearings.

The above instructions should be carefully observed in order that the bearings may not be too tight and to prevent wiping of the babbitt lining.

All solid bearings are given a good running fit suitable for the speed and type of lubrication. Wherever a solid bushing is replaced it should be reamed to such a size that there will be $\frac{1}{1000}$ to $\frac{2}{1000}$-inch running fit.

Maintaining Compression

After the engine has been run for 10 or 15 hours it is well to check up the compression and see that it is equal in all of the cylinders. This may be done by turning the engine over slowly by the starting crank or propeller and comparing the resistance in each of the eight cylinders. The compression can be tested more accurately by removing a plug and inserting a pressure gage in each cylinder successively and noting the pressure recorded in each cylinder. A gage reading to 100 pounds should be used for this purpose.

Loss of compression is generally due either to valves not seating perfectly or insufficient clearance between the valve stems and rockers. Leaking spark plugs or piston rings are other causes less often found.

SECTION XI

THE THOMAS-MORSE ENGINE

In general appearance the Thomas engine resembles the Sturtevant as can be seen in Fig. 82, where it is shown mounted

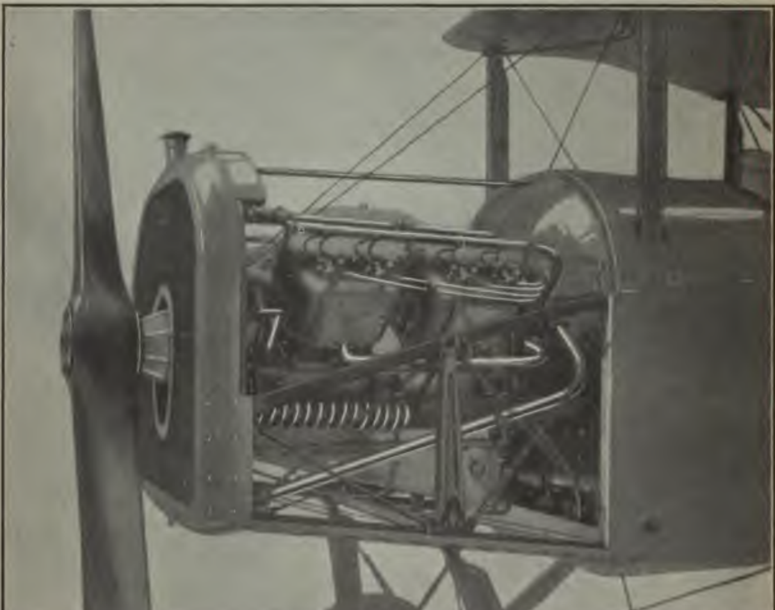


FIG. 82.—Thomas motor.

in a Thomas plane. This shows the engine mountings and also the coil of cooling pipes for the lubricating oil.

This is also shown in the detail of the oil system in Fig. 83.

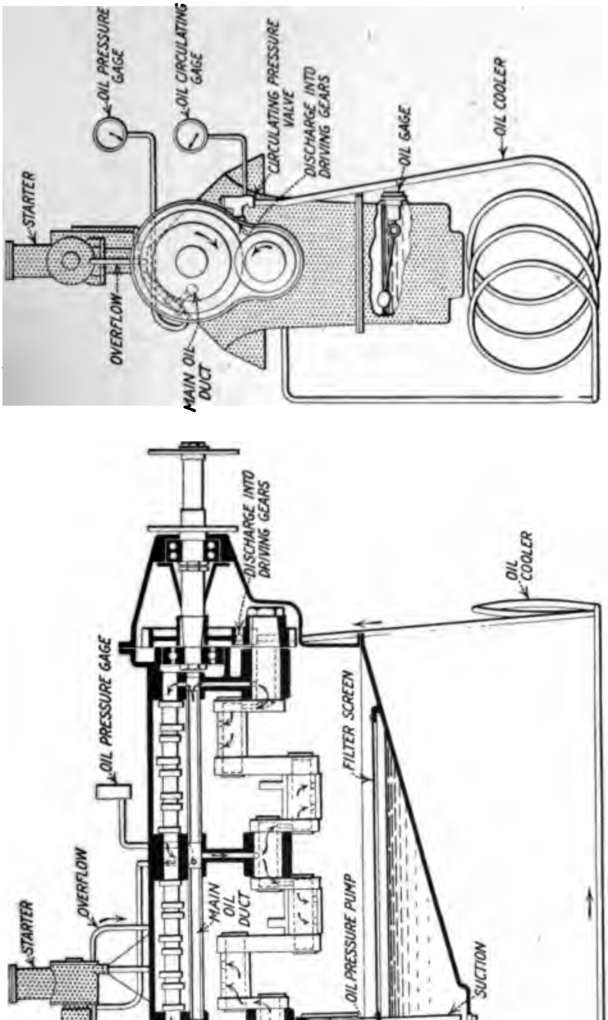


FIG. 83.—Oiling system of Thomas engine.

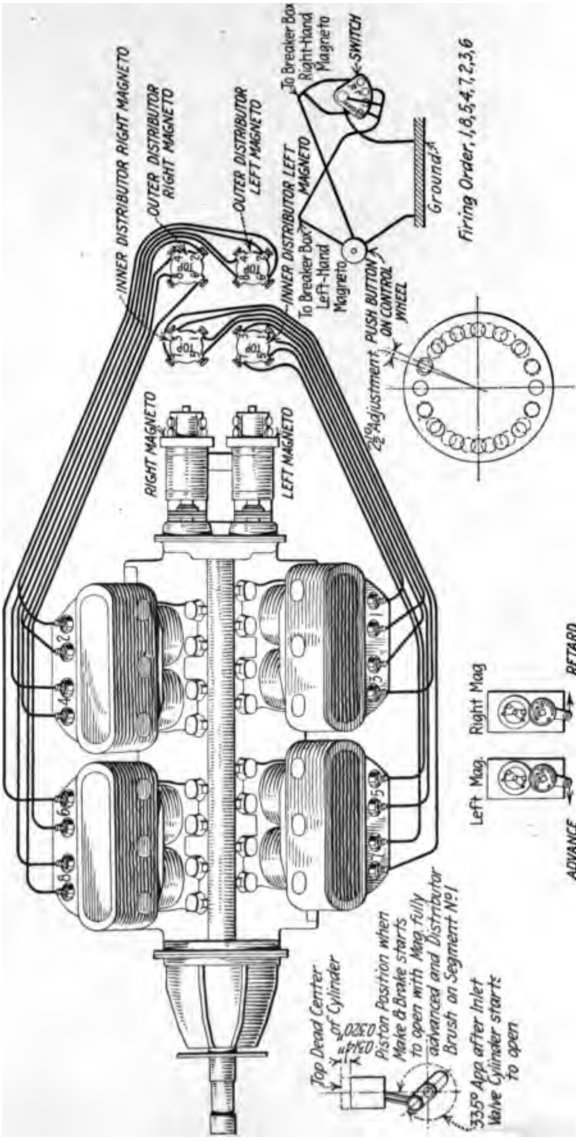


Fig. 84.—Ignition wiring diagram of Thomas engine.

These engines run at 2000 to 2100 r.p.m. and according to size, the 135-horsepower at 2000 r.p.m., the larger 150-horsepower at 2100 r.p.m.

The ignition system is shown in diagram in Fig. 84. This will be of considerable value when overhauling the engine or

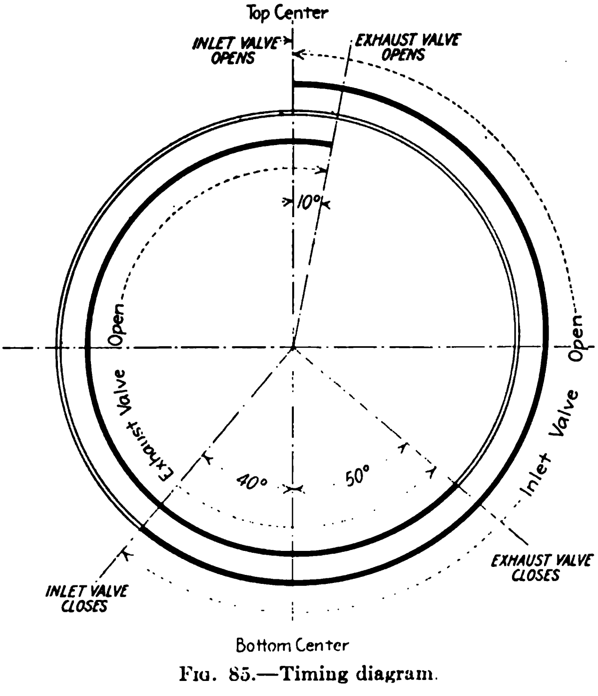


FIG. 85.—Timing diagram.

in tracing ignition troubles. The timing diagram is shown in Fig. 85. This engine is also equipped with the Christiansen starter.

SECTION XII

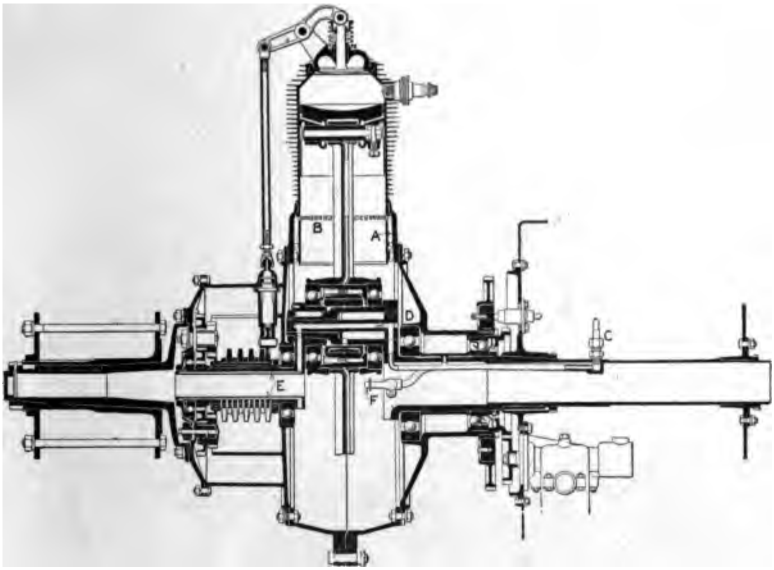
GNOME AIRPLANE ENGINE

The Gnome type of engine, Fig. 86, is a highly interesting mechanism, consisting of nine radial cylinders held in a central

FIG. 86.—Gnome engine in test frame.

crank case, in which the crankshaft is stationary and the cylinders *revolve,* carrying the propeller with them. The odd number of cylinders makes it possible to secure a uniform period of explosion; for when it is remembered that each alternate cylinder fires as it revolves, it will be seen how this affects the sequence.

While the Gnome is simple in principle the design is intricate, even though refined through years of patient study and experiment. It cannot fail to elicit admiration, but it also presents problems in manufacture which require the best mechanical brains for their solution. The operation of the motor will be considered after the construction of some of the many parts.



FG. 87.—Section of Gnome motor.

The cylinders are machined from 6-inch solid steel bars, which are sawed into blanks 11 inches in length and weighing about 97 pounds. The sectional view, Fig. 87, shows how they are constructed.

The mixture of gas and air is forced into the crank case through the jet inside the crank at *F*, and enters the cylinder when the piston is at its lowest position, through the half-round openings in the guiding flange and the small holes shown at *A* and *B*. The returning piston covers the port, and the gas is compressed and fired in the usual way. The exhaust is through a large

FIG. 88.—Cam action of Gnome engine.

single valve in the cylinder head, which gives rise to the name "monosupape," or single-valve motor. The lubricating oil comes in at *C*, through the stationary crankshaft, goes through the stationary crankpin at *D*, and floods the bearings at *E*.

Some of this oil also goes to the crankpins and is thrown by centrifugal force through the tubes on the rods, through the piston-pin bearings, and in this way oils the piston pins as well as the cylinders. The latter also receive all oil that happens to fly out of any of the holes in the crank case.

With the motor running at 1200 r.p.m. the oil feeds out very rapidly by centrifugal force, and it has been found, in fact, that the oil tubes are unnecessary on the connecting rods; for if the tubes are omitted, the oil flows out of the crankpin hole and makes a bee-line for the hole in the piston-pin end, just as though it were being conducted along the rod by the tube shown.

The other end of the motor is illustrated in Fig. 88, the cover being removed so as to show the cams and the gears that drive the oil and fuel pumps. There are nine oil holes in the crankpin which feed the oil to nine cams, one being shown at *A*, Fig. 88. The hole is at the base of the incline in each case. These cams, incidentally, are made of a steel of 264,000 pounds tensile strength. The cam roller *B* picks this oil up and carries it over the cam surface, some of it reaching the small oil holes on each side of these rollers and oiling the bearings of the rollers themselves. The surplus oil from here feeds up through the valve-rod guides, which, it will be remembered, are running 1200 r.p.m. From here it feeds through the ball joint *D*, through the hollow valve rod *E* and oils the pin at *F*. There is also sufficient oil at this point to strike a groove on the under side of the valve lever and feed along to the lever bearing *G*, so that every bearing is well oiled from the central supply. This, however, requires a large amount of oil, a characteristic of the rotary type of motor.

OVERHAULING THE GNOME AIRPLANE ENGINE

The Gnome airplane engines now being built for the United States Aviation Corps make it important that their construction and maintenance be understood by the skilled men who must look after them. In order to show just how these engines are overhauled, some of the more essential operations are illustrated, reproducing the methods from the practice recommended by the French builders and users.

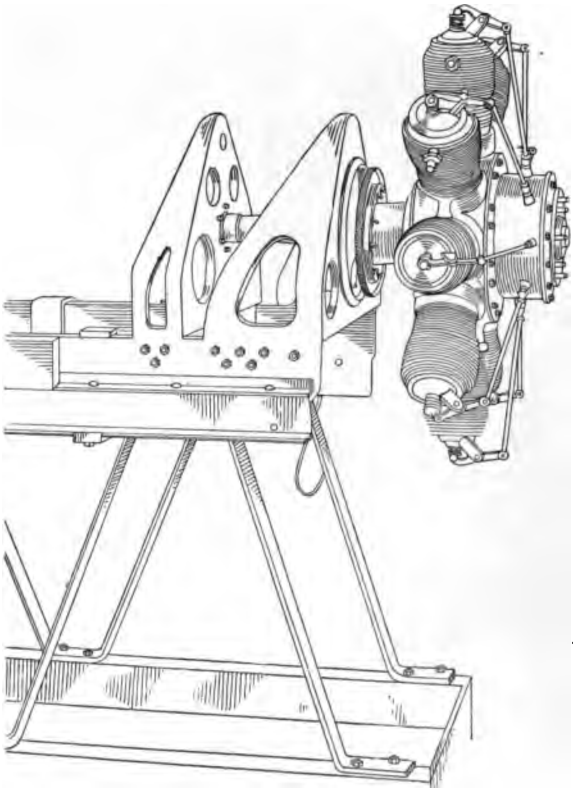


FIG. 89.—Engine on stand.

The engine must be taken from the frame and placed on a test stand. To do this, the outer nut that holds the centralizing plates must be removed and the crankshaft forced out of the conical bore of the main bearer plate by using an extractor made for this purpose. The extractor is very similar to what is known as a "wheeljack" in automobile repair work. The motor is fastened on the repair stand in the same way that it is held in the plane as shown in Fig. 89. Mounted in this way, the engine can be rotated and is accessible for dismantling or timing.

The brass wires are disconnected from the spark plugs and coiled up loosely at the distributor terminal, as in Fig. 100. The spark plugs are taken out and, after the points are thoroughly cleaned, are put into a box to avoid damage. Next, one of the tappet-rod cup ends is detached from its ball end. This can easily be done by selecting a cylinder where the valve is closed and rocking the lever to open the valve with one hand while the cup end is lifted away with the other. The valve case is unscrewed with the proper wrench by turning to the left. It does not matter with which cylinder one starts, but afterward the valves from every alternate cylinder are placed in their proper order on the bench or in a box. It is best to have a box with nine compartments, or nine separate boxes, all numbered for this work. In some cases the cup ends of the tappet rods are fitted with special clips that must be removed before the cup ends can be detached.

The special central, or umbrella nut holding the ball race in the front cover is unscrewed, and then all the nuts in the front cover of the gear case are removed. This cover must then be replaced with a special extractor, shown in Fig. 90, which is held in place by three nuts. The extractor screw should bear on the end of the crankshaft and not on the tubular liner inside the shaft. This will remove the front cover with the ball race, and the crankshaft gear can be pried off with a pair of pinch bars by using one on each side. The camshaft can be removed by giving it a twisting motion, turning it so that the cams clear the tappet rollers. It is not usually necessary to dismantle the cams from their sleeve for cleaning purposes.

The extractor, shown in Fig. 90, is not removed from the front cover, but the front cover and the extractor are replaced upon the valve-gear case, and the frontcover flange is fastened with some of the bolts to the valve-gear case. Then the hexagon nut is removed from the studs that hold the valve-gear case to

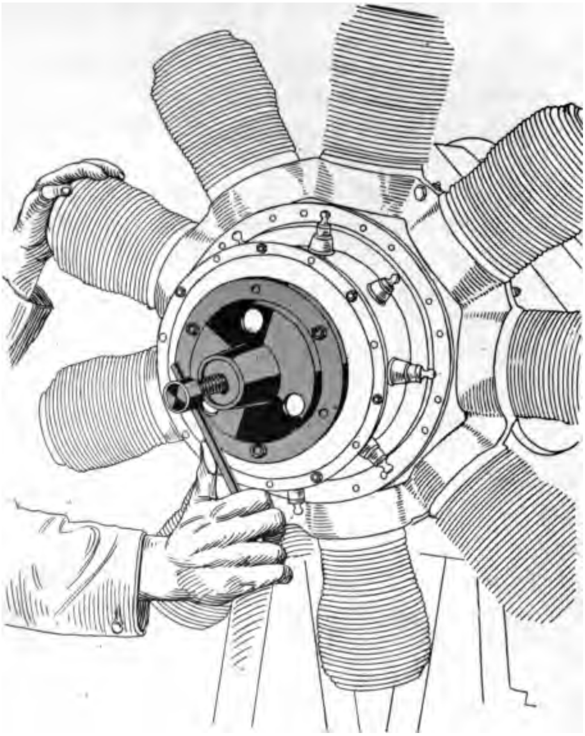


Fig. 90.—Withdrawing valve-gear case.

the crank case. Care must be taken in using this extractor not to put on sufficient pressure to bend the crankshaft.

Removing Short Crankshaft

The next operation is to remove the short end of the crankshaft, which has a long taper fit and is fastened with a hexagon nut. This nut has a locking screw that must be removed before it can be taken off. Then the special puller, shown in Fig. 91, grips under the edges of the crank web while the outer arms press against the mother rod so that only the small part of the crank

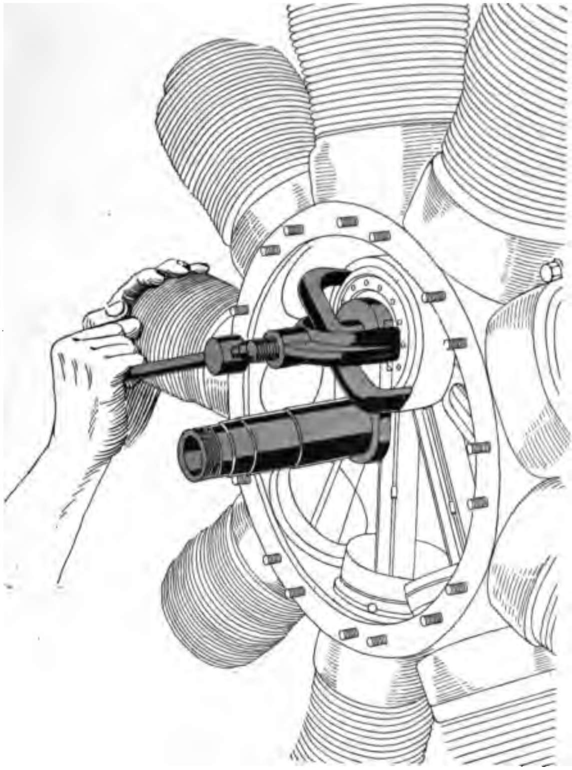


FIG. 91.—Drawing off the short end of the crankshaft.

is removed. If the crank does not start readily with the pressure alone, a gentle tap on the head of the screw at the same time pressure is being applied will usually bring it off without difficulty. A special clip on the back side of the short-end crankpin pulls the ball race away with the short end.

Next, the brass screws in the connecting-rod wristpins are removed with a broad-pointed screw-driver. Then, with the special screwjack shown in Fig. 92, the corresponding wristpin is removed. The screw of the dog goes into the thread in the

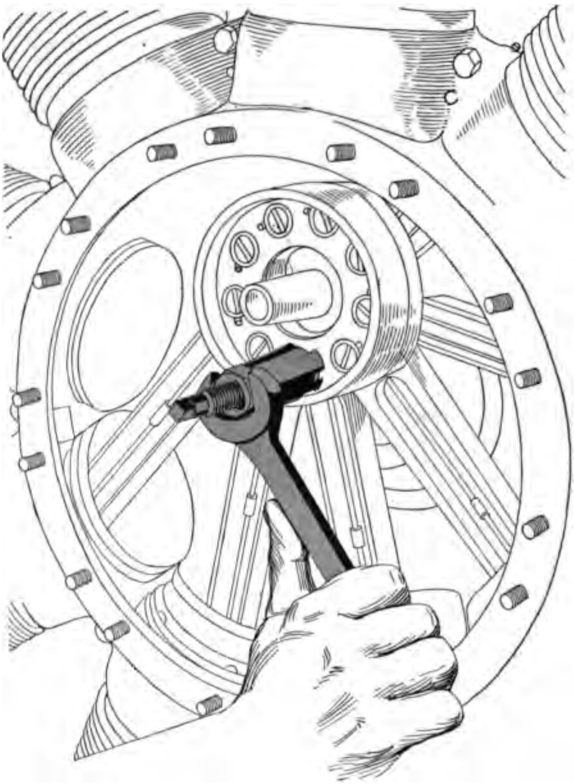


FIG. 92.—Withdrawing wristpins and screws.

wristpin, and by turning the hexagon nut the pin is easily pulled out through both the small connecting rod and the mother rod. Care must be taken in doing this to avoid damage to any of the parts. It is better to remove pins Nos. 5 and 6 first.

Before taking the wristpin entirely out of the mother rod, the connecting rod should be held with one hand so that the piston does not drop to the bottom of its cylinder, as shown in Fig. 93. The wristpin is removed from the extracting jack, and the brass screw is put back in place, as it is the screw that carries the number

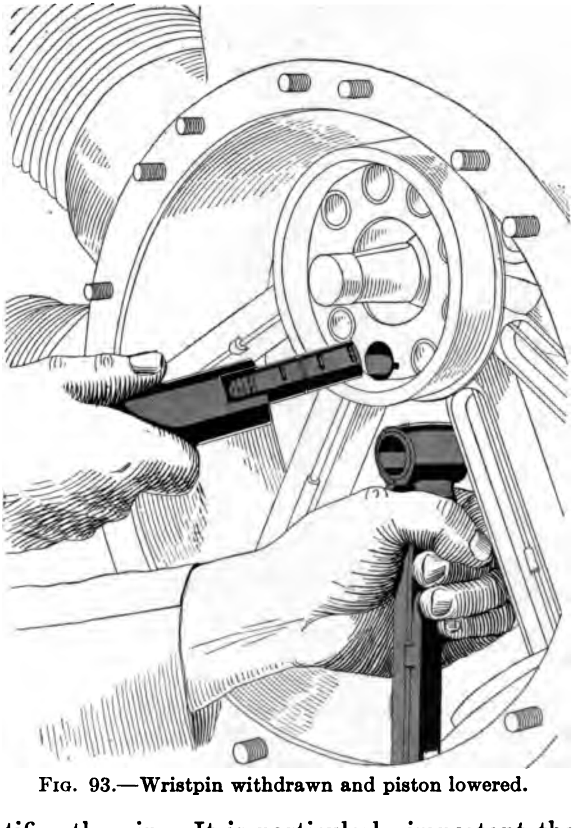


FIG. 93.—Wristpin withdrawn and piston lowered.

and identifies the pin. It is particularly important that No. 1 wristpin go in its proper place, as it has an extra longitudinal oil groove. The piston and connecting rod can then be removed from the cylinder.

This is done by carefully lowering the piston, turning the connecting rod, as shown in Fig. 94, and lifting the piston from its cylinder. Great care must be taken in all operations to avoid

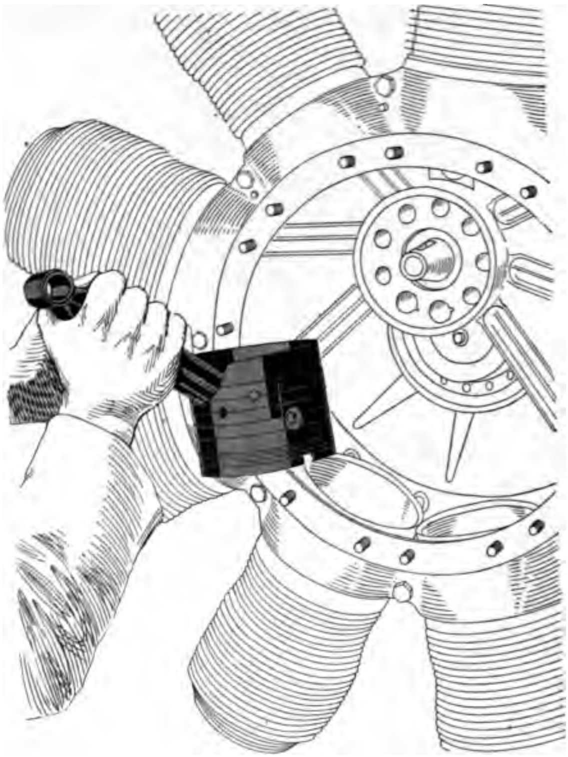


Fig. 94.—Piston and connecting-rod being removed.

damage of all kinds. All parts of the piston are extremely delicate, and no bruising or marring of any kind can be permitted.

Removing Crank Case and Mother Rod

Before the complete crank case can be removed, the nuts must be taken off the studs that hold the crank case to the thrust cover flange at the back. Spring washers will be found under each nut and should be cared for when removing. Two nuts are generally left at opposite points until all the rest are removed. Then, two men hold the cylinders while these nuts are removed, and then hold the cylinders and crank case while the mother rod is being taken out.

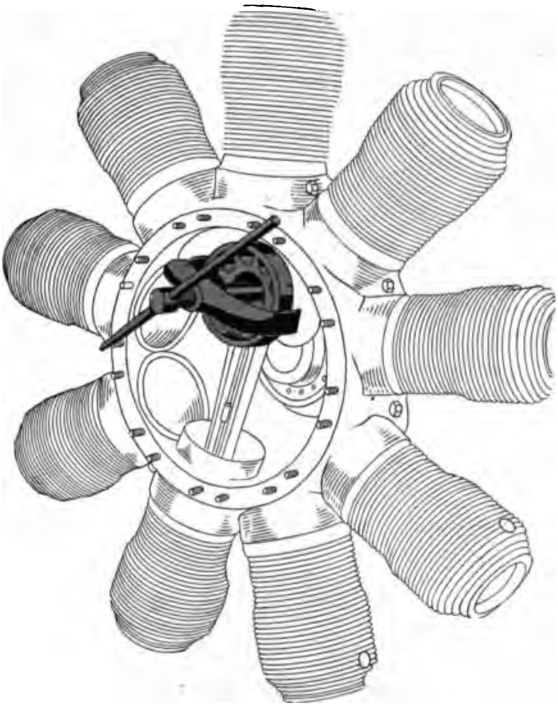


FIG. 95.—Mother rod being withdrawn.

The mother rod has to be removed at the same time the crank case is taken from the thrust plate, as its piston cannot be withdrawn from the cylinder until it is clear of the crankshaft. In order to do this, the puller shown in Fig. 95 is used. The jackscrew must be operated very carefully and only as fast as the men move the cylinder and crank case away from the thrust plate, for it must be remembered that the crankshaft remains with the thrust plate, but that the cylinders, crank case and mother rod have to be removed at the same time to avoid any strain on the wristpin. The ball race may come away with the mother rod, or it may remain on the crankshaft. In the latter case it

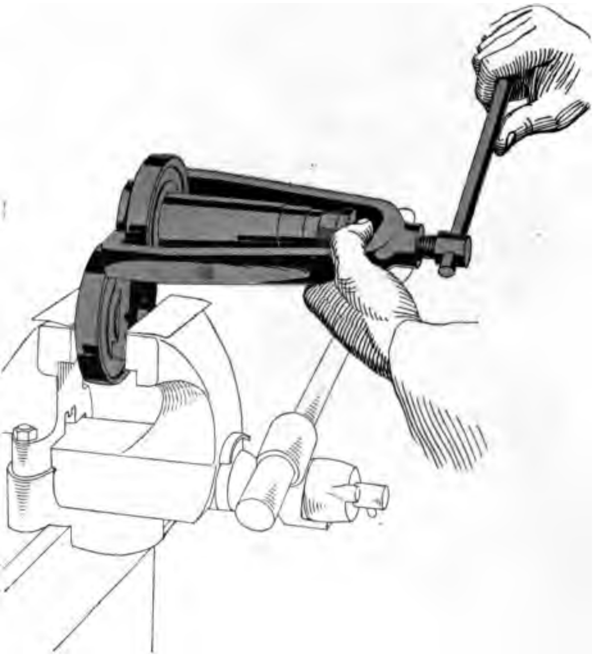


FIG. 96.—Removing ball race from short-end crankshaft.

can be removed by a special puller made for this purpose and shown in Fig. 96.

When the mother rod has been removed from the crankshaft, it is also turned at right angles in the cylinder and removed in the same way as the piston previously referred to. When the crank case is removed, it is laid on its side in a special stand having a recess to clear the studs and a shoulder that keeps it from slipping off. Every possible precaution must be taken against accidental damage to the cylinders. It is not at all necessary to remove the cylinders from the crank case for thorough cleaning, and in fact this should never be done except when it is necessary to replace a damaged cylinder.

In order to dismantle the thrust cover, it is usually put back in place on the crank case, as this lies on its proper stand. This is merely for convenience.

The distribution case, which is shown being removed in Fig. 90, carries a ball bearing and the reducing gears for the oil and fuel pumps. This ball bearing is removed by gently tapping with a round surface punch, tapping entirely on the outer case. By tapping first on one side and then the other, it requires but very little pressure to remove the ball race. The upper or obturator piston ring is easily removed by the fingers, by taking hold of one end only and lifting it just clear of the groove. Then by turning it away from the gap, it will release itself. It should then be removed by catching hold of the two ends and gently springing outward until it can be lifted clear of its groove. The cast-iron piston ring can be removed in the same way. Great care is necessary to avoid distorting these rings, as they are both very light, this being particularly true of the upper or obturator ring.

Handling the Piston

With the three rings removed, the piston is placed head down on the bench, the cotter pin removed from the head of the taper screw that locks the wristpin, and the screw removed by means of a socket wrench. The piston pin is driven out by a special punch that is placed against the end of the pin *at the split end* where the locking screw enters. It can then be easily driven out the other end. The weight of the piston is usually enough to withstand the light taps necessary for this operation. If not, the left hand may be rested in the position shown in Fig. 97. Here, the thumb and forefinger hold the punch, the little finger holds the connecting rod away from the skirt of the piston, and the weight of the hand holds the piston on the bench. It is necessary to be very careful in keeping the connecting rod away from the piston, as the skirt is extremely thin and easily cracked.

FIG. 97.—Removing piston.

After the piston, pin, rings and connecting rods are completely apart, they are washed in kerosene. The color and markings of the piston and rings are carefully examined. The piston pin should be smooth and not show signs of wear. If there is any indication that the piston has seized, or if it is scored in any way, it should be carefully smoothed down. The piston should also be checked with a micrometer to see whether it is round or oval. If it is over 0.001 inch out of round, it should be replaced. Marks of burnt oil can be removed with very fine abrasive cloth. If there is an accumulation of carbonized oil or black jelly inside the crown, it should be thoroughly cleaned before reassembling. The obturator ring should show a bright edge all around and not bear at the foot except at the

FIG. 98.—Cleaning and washing mother rod.

extreme end. If this is not the case, a new ring must be put in. The cast-iron ring should be bright all around.

All carbon and burnt oil should be carefully scraped from the inside of the piston and also the piston head.

After all discoloration has been removed by means of fine abrasive cloth, the piston should be placed in a bath of gasoline and cleaned with a brush. The piston-pin holes should be thoroughly syringed out through these pin holes and around the ring groove. In the same way the small oil holes leading from the inside of the piston to the wide piston-ring groove should be cleaned with a wire and syringe.

All the connecting rods should also be cleaned in kerosene, wiped carefully and any discoloration from burnt oil removed by fine abrasive cloth. If one of the ball races has remained in the mother rod, it can be removed by gentle tapping with a hammer and punch from the other side. After the rod is thoroughly cleaned, the oil pipe is washed out with a syringe filled with gasoline, as in Fig. 98. This illustration shows a small connecting rod supporting one end of the main rod with a leather washer to make a joint at the bottom of the piston-pin hole, and also a washer around the nozzle of the syringe. This method is used for cleaning all the oil pipes and similar passages, which it does very thoroughly.

Should new piston rings be necessary, they should be checked very carefully to secure proper clearance. If they are too wide, they can be worked down with a fine file; but it is found preferable to grind them on a piston ring or similar machine. The cast-iron piston rings should have a clearance of 0.002 inch sidewise in the groove. The packing rings for the obturator should also be reduced until the same clearance is obtained.

Testing Connecting Rods

After the connecting rods are cleaned, they should be tested by placing a pin through each end and mounting on a V-block, as in Fig. 99. Then a surface gage is used on each end of the pin, which shows the alignment of the two ends of the rod. The cylinder shown is simply used to support the rod. The amount of clearance between the rings and the groove should be tested with a feeler in the regular way. A straight-edge should also be laid along the side of the piston to see that the cast-iron ring does not project at any point. Should it be found to project, the inside of the ring can be eased out with a half-round file.

In assembling the piston pins, it should be remembered that the split end belongs in the boss that has the locking screw. This means that the other end of the pin should be pushed through this boss first. At the same time it should be observed that the oil pipe on the connecting rod is on the opposite side to the locking screw and that the gap in the piston skirt is at the

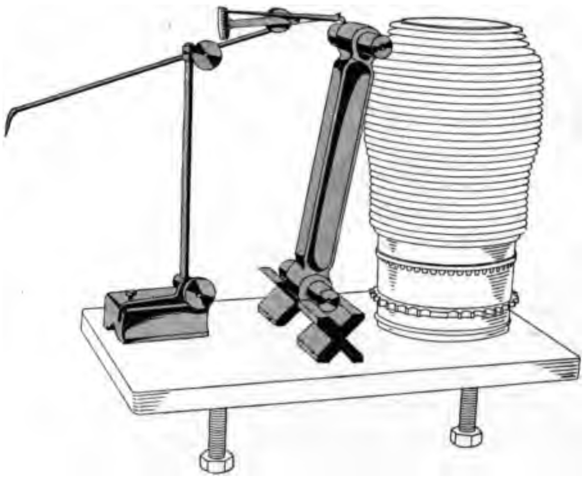


FIG. 99.—Checking alignment of connecting-rod bushes.

right-hand side when the locking screw is next to the operator. It is also necessary to see that the large end of the taper hole of the piston pin is up and that it comes in line with the capped hole for the locking screw.

If the pin is not entering in exactly its proper position, the end can be clamped lightly in a vise that is protected by copper or lead jaws and turned slightly until the holes come in line, after which it can be pushed into place and driven home with a special punch and hammer. The locking screw should now be screwed tight into place and the cotter pin put through the head of the screw so that it comes against the inside of the piston skirt so as to prevent unscrewing. Care should be taken that no small particles of metal dust or burrs remain in the pin slot. They should be picked out, a magnetized scriber being extremely useful in this connection.

The piston rings are put in position by reversing the process of taking them out, care being taken not to spring the ring any more than is absolutely necessary. Then the large ball bearing is put into position on the mainshaft, the shaft assembled in the thrust cover by gently tapping the ball race into position, and the thrust race can be pressed home by a special draw sleeve made for this purpose. The special wrenches that are needed in almost every instance are usually supplied with the engines.

CLEANING CYLINDERS

The walls of the compression space of the cylinders should be thoroughly cleaned before the pistons are again assembled. This can be done with a specially shaped scraper, and the outside of the cylinders are also cleaned and polished to remove any marks of heating which may appear. The cylinders are then thoroughly washed with gasoline, particular attention being paid to the holes that form the inlet port for the cylinder gases. Each hole is separately sprayed with the gasoline syringe, so as to be sure that every passage is thoroughly cleaned. Before pistons and connecting rods are replaced in their cylinders, they are thoroughly washed in a gasoline bath, and the syringe is used for cleaning out all corners of the piston and pins.

In replacing the pistons the obturator gap should be brought to the same side of the piston as the connecting-rod oil pipe and placed 30 degrees on the opposite side of the piston pin to the clearance cut in the skirt of the piston. The gap in the cast-iron ring should be opposite this, and the gap in the ring that goes beneath the obturator ring should be 90 degrees to it on the side opposite the piston clearance.

The mother rod with its piston is first inserted in cylinder No. 1 by reversing the process described in removing it. It is necessary to watch the obturator gap very closely so as to enter it into the cylinder positively, but easily; and the piston should then be worked up and down slowly and turned at the same time

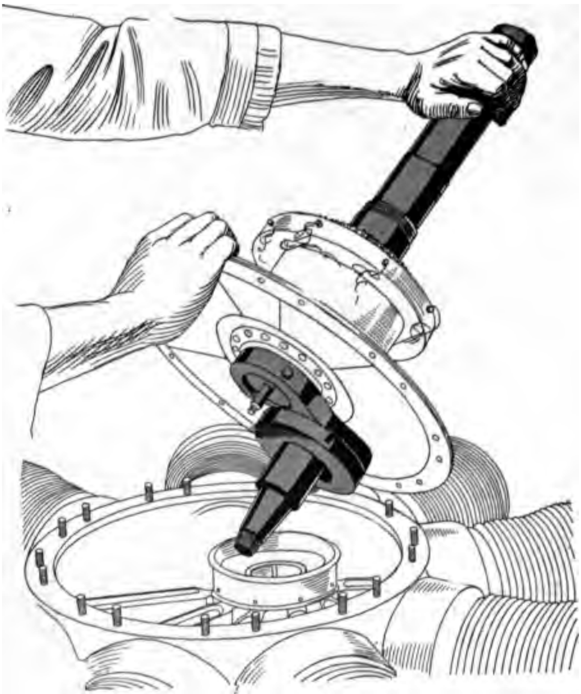


FIG. 100.—Assembling crankshaft.

to bring it to the correct position. Before this is done, some crude oil should be put in the cylinder to avoid any semblance of sticking. The clearance cut in the piston must be in its correct position on the trailing side of the cylinder. Starting with No. 2 connecting rod and piston, the engine is assembled in much the same way that it was taken apart.

Before the small crankpins are put in, they should be thoroughly cleaned with gasoline; and this should be forced through the oil passages to make sure that they are perfectly clear. A special tool is used for holding the connecting rod in line with the small crankpin, and it is customary to put in pins Nos. 5 and 6

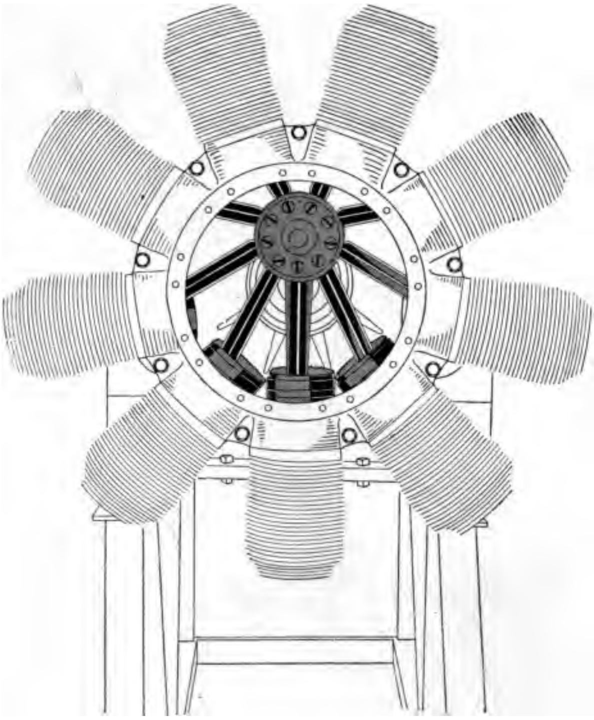


FIG. 101.—Piston and rods in place.

first, as these take the weight of the mother rod and hold it steady. The pins can then be easily entered in their proper positions and tapped home with a light hammer and punch, care being taken that the small lug which prevents the pins from turning is in line with its recess. After each pin is assembled, the rod should be moved about to make sure that the pistons so far assembled are free in all positions. There should be a little side play at each end of the small connecting rod.

Then the thrust cover, which has been completely assembled, is put into place, as in Fig. 100, threading the crankpin through

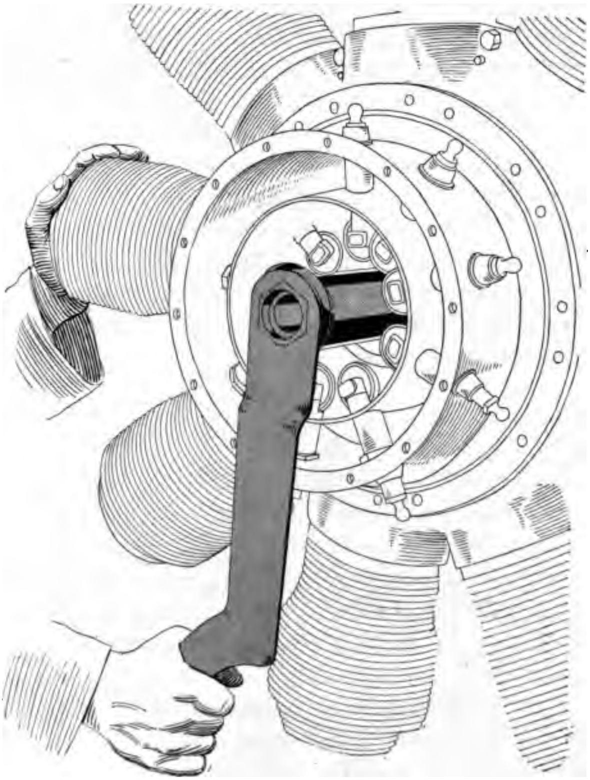


FIG. 102.—Pulling valve-gear case home.

the mother rod, as shown. The mother-rod ball race should be worked in easily. The thrust cover can then be slipped over the studs, and some of the nuts put into place. These nuts should not be screwed home, however, but only sufficiently to hold the cover to the crank case while the whole thing is being mounted on the engine stand, as shown in Fig. 89. Fig. 101 shows the pistons all in place.

Although the ball race in the mother rod is not all the way home, it can easily be pulled into place with a sleeve and nut. From here on, the work of assembling is simply the reverse of that previously described in the earlier operations of taking the motor apart and only requires good judgment on the part of a first-class mechanic. No other should tackle a job of this kind.

After the short end of the connecting rod is in place, the valve-gear case is put back and forced home by using a sleeve, nut and special wrench, as in Fig. 102. The operating nut is screwed into the sleeve until the thread disappears, and is then slipped loosely over the shaft, avoiding the tappets by rotating slightly. The internal thread on the operating nut will engage with the thread on the crankshaft, which should now be screwed up as far as possible with the wrench shown.

Timing the Valves

The sleeve is rotated by hand until the flange bears against the ball-race housing. Then, with the wrench on the sleeve, the sleeve and engine are revolved together. This forces the ball race onto the shoulder of the crankshaft. Should it appear to be too tight a fit, it can be helped home with a few blows from a rawhide hammer on the front flange. To withdraw the sleeve, the operating nut is slacked off from its thread on the crankshaft. It should be noticed that No. 3 cylinder and valve are not operated by No. 3 tappet and No. 3 cam. The accompanying table gives the correct relation and shows that No. 3 cylinder and valve are operated by No. 1 tappet and No. 1 cam, also that No. 2 cam operates No. 2 tappet. This unsymmetrical numbering has come from a rearrangement of the cams in a change of design of the engine and the retention of the original numbers.

NUMBERS OF CORRESPONDING PARTS OF GNOME ENGINE

Cylinder, Valve, Tappet rod Nos.	1	2	3	4	5	6	7	8	9
Tappet, Valve-gear case Nos.	9	5	1	6	2	7	3	8	4
Cam No.	9	5	1	6	2	7	3	8	4

Fig. 103 shows that No. 3 valve has been put into No. 3 cylinder and its tappet rod connected. Before the tappet rod is put

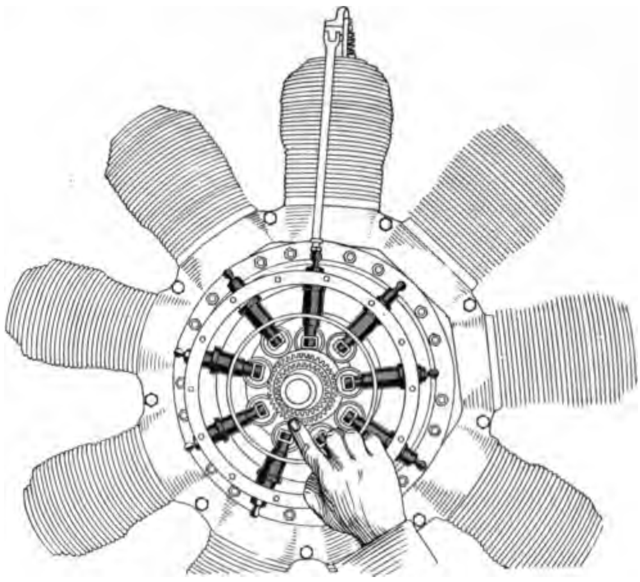


FIG. 103.—Assembling valves and camshaft.

on, a test is made with a syringe to see that there is a free passage for oil from the cup end to the fork end of the rod. The engine is turned so that No. 3 cylinder is at 85 degrees from the vertical, as shown. In this position the cam that operates No. 3 tappet should be turned clockwise in the direction of the pointing finger until the rise on the cam, when it is opening the valve, is immediately below the No. 3 tappet roller. The angle at which this cylinder is standing can be checked by using a timing protractor held against the tappet rod, as in Fig. 104. Before the front cover is assembled, the camshaft should be turned in a clockwise direction until the rise of the cam has taken away all end play of the tappet rod. A syringeful of castor oil should be injected into the case after the front cover is put on. The front cover can be slipped into position by noticing that the markings on the outside, or satellite, gears correspond with the markings on the crankshaft gears. Two pegs, one on each side of the front cover, are useful to lead it into position.

Some of the bolts are now put loosely into the front cover and, before they are tightened up, the ball race is tapped into position on the crankshaft. Then the central nut is screwed up hard, and the front cover bolt is tightened evenly all the way around. This leaves only the valves, tappets and spark plugs to be assembled, the valve cages being screwed into the cylinder heads by means of a special box wrench.

Before putting the spark plugs in place, the timing should be checked over, to be sure that the valves are opening at 85 degrees past the top vertical center and closing at 120 degrees past the same center on the next revolution. All the plugs are assembled with their joint washers, and the wire from the distributors is attached to their respective plugs. The wires should be securely fastened, but not too tightly, as there should be no tension in them after they are fixed. In handling the engine from the erecting stand to the plane, the main bearing plate should first of all be put upon the bearing. It should be complete with oil pump and air compressor, but not magneto or carbon brush-holder. The centralizing plates should also be assembled. The engine should now be lifted into position, passing the long-end crankshaft through the main bearer plates, and the nuts threaded on and passed through the centralizing plates, when the large nuts should be put in place.

The magneto should next be put in place. The No. 1 cylinder is set 18 degrees in advance of the top vertical center. This can be done by using the protractor shown in Fig. 104. The magneto should be set so that the contact breaker points are just separating.

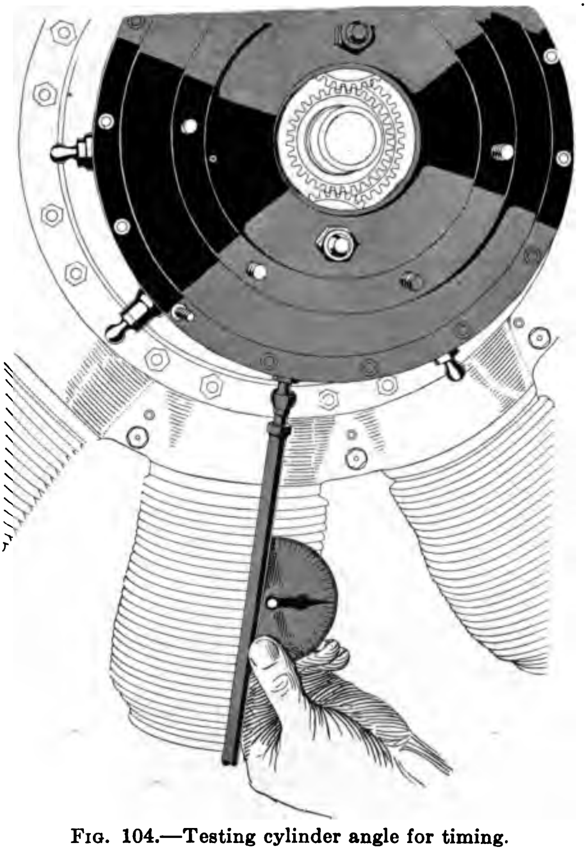


FIG. 104.—Testing cylinder angle for timing.

In these positions the magneto gear is brought into mesh with the gear on the engine, and the magneto is fastened up with its three screws. The magneto screws are locked with wire threaded through their heads.

CYCLE OF OPERATION

The Gnome engine works on the four-stroke cycle, with a fixed ignition, this being set to take place from 15 to 20 degrees before the top dead center, or 18 degrees on an average, as shown in the diagram, Fig. 105.

When the cylinder has turned through 85 degrees from the top center, the exhaust valve begins to open, and the products of

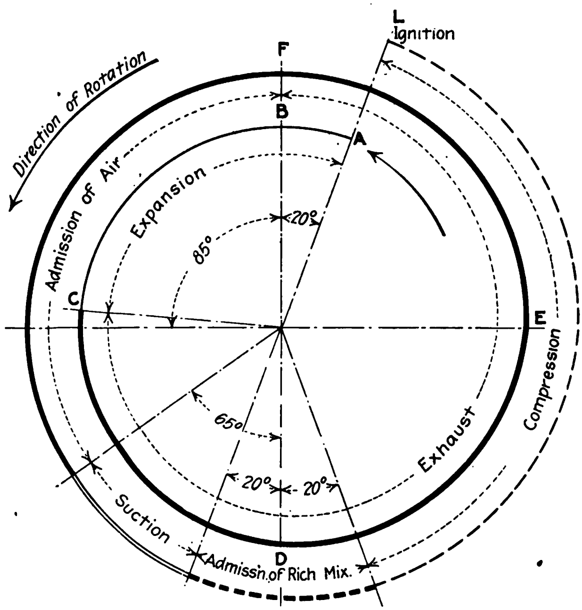


Fig. 105.—Timing diagram of Gnome engine.

combustion commence to flow to the atmosphere. The exhaust stroke continues until the piston returns to the top dead center.

With the valve still remaining open, the piston descends on the induction stroke, drawing air into the cylinder through the valve. At 65 degrees before the bottom center is reached the valve closes. *The piston* continues to descend and creates a partial vacuum in the cylinder until it is 20 degrees from the bottom center. At this point the piston uncovers the ports which have been drilled in the cylinder wall and makes connection between the cylinder and the crank case, drawing a very rich gasoline mixture into the cylinder. This rich mixture is diluted by the air already in the cylinder, the resulting mixture being a good combustible gas. The ports in the cylinder remain uncovered until the piston reaches a point 20 degrees past the lower center on the return strokes.

When the ports close the piston ascends on the compression stroke and when 18 to 20 degrees from the top center the ignition occurs, after which the cycle of operation is repeated. These are average figures and may vary slightly with individual engines. Each engine is supplied with a special set of timing figures which should be adhered to.

TIMING OF THE ENGINE

The exhaust valve in the head opens at 85 degrees past the top center and closes at 65 degrees before the bottom dead center. In order to time the engine it should be mounted on supports in the frame, with the front nose extension removed, together with the front cover with its ball race and the two pairs of reducing or satellite gears. Turn the engine in the direction of rotation, which is to the left, or anti-clockwise, and adjust the valve-rod cup ends until there is a clearance of 0.5 millimeter between the exhaust valve levers roller and the exhaust valve of each cylinder when the valve is shut. Then turn the engine in the direction of rotation until cylinder number is 85 degrees past the top dead center, or nearly horizontal.

Turn the camshaft in the opposite direction, or clockwise, until the cam for cylinder No. 1 is about to commence to lift the valve. With the camshaft in this position, take the front cover fitted with the satellite pinions and turn the satellite wheels so that the two teeth marked with the letter *O* are pointing toward each other. That is, they will be diametrically opposite each other when seen through the ball bearing opening from the front. Fit the front cover on the valve-gear case so that the gears mesh and the bolt holes are in line.

If two steel rods are pushed in diametrically opposite bolt holes they will assist in the correct registering of bolt holes and gears. The gears should mesh without the least effort.

When assembled turn the engine until the marked teeth appear diametrically opposite each other, as before, to verify the setting, as, if the satellites are not both meshing with similar teeth, breakage is sure to occur.

As soon as the front cover is pushed into place put on the nuts and fit the ball race in position. Turn the engine round to see that it is quite free and verify the opening of the valves at 85 degrees past the top dead center. Continue to rotate the engine and verify the closing of the valves at 65 degrees before bottom dead center. Adjust the tappet clearances again if necessary so that the timing for all valves shall be as near the same as possible. The tappet clearance should be about 0.5 millimeter when the engine is cold, this being increased somewhat when the engine is hot.

IGNITION

With the average engine ignition takes place 18 degrees before the cylinder reaches the top center. This can be tested by turning the armature of the magneto in the direction of rotation until the points of the contact-breaker are just separating. When in this position place the gear wheel of the magneto in mesh with the gear on the engine and fix the magneto to the main bearer plate.

Care must be taken to see that the carbon brush has just come into contact with the brass segment of the distributor when the engine and magneto are in the relative position above mentioned.

LUBRICATING SYSTEM

The oil pipes of these engines have two equal deliveries and they can, therefore, be connected to either of the oil unions on the crankshaft. Oil is usually fed by gravity from the tank to the pump, but in some cases an oil-pressure feed is used. The bell glass of the sight feed is half filled with air and the stroke of the pump plunger is indicated by a pulsation. The number of these pulsations is in constant ratio to the number of rotations of the engine, there being 9 pulsations for each 100 revolutions of the engine. Thus, at 1000 r.p.m. of the engine there should be 90 pulsations, with 99 pulsations at 1100 r.p.m., 108 pulsations at 1200 r.p.m.

RUNNING THE ENGINE

Priming the cylinders through the exhaust valves for starting is unsatisfactory and the engine can best be started in the following manner: Turn the engine round until a cylinder is at the bottom with the valve open. With the switch off, turn on gasoline until it begins to run out from the open valve, then turn off. With the switch off, turn the engine over twice. Then throw on the switch and begin opening the gasoline regulating valve, at the same time swinging the propeller, which should start the engine without difficulty. On engines where the gasoline is fed under pressure and there is no hand pump or auxiliary starting supply pipes fitted, prime the cylinders through the valves, as is usual for ordinary engines. After priming, switch on spark and start up by swinging the propeller.

When the auxiliary starting pipes are fitted prime the engines by one or two strokes of the hand pump, switch on and start up, regulating the gasoline by means of the usual valve.

On engines where the gasoline is fed by pressure from an air pump, close the regulating valve, pump up pressure in the tank by means of the hand pump and see that the regulating valve is correctly adjusted. This adjustment should maintain a pressure of 4 pounds per square inch when the engine is running.

Turn on gasoline to prime engine, throw on switch and swing the propeller to start, regulating the gasoline supply by adjusting the valve in the usual way.

It sometimes happens that when priming the engine according to instructions, the cylinders may become too full of gasoline. This can be detected by the gasoline leaking from the valve. Should this occur it is advisable to turn the engine backward once or twice in order to clear the valve of any superfluous gasoline. Unless this precaution is taken it sometimes happens that, in the event of a backfire through the valves when starting, the superfluous gasoline outside the cylinders might ignite and cause damage to the airplane.

HANDLING THE ENGINE IN FLIGHT

The engine should be fitted with a propeller to give from 1200 to 1250 r.p.m. with the throttle wide open in horizontal flight. Each engine should be tested in flight to determine the difference between the speed in the air and the speed on the ground. This difference may vary from 50 to 200 r.p.m. and in some cases to even 300 r.p.m. In any case the speed of the engine should not exceed 1250 r.p.m.

CLIMBING AND TURNING

On a very steep climb of short duration, or a very short turn, the engine will be temporarily overloaded, causing a slight decrease in the number of revolutions per minute. When the gasoline is fed by an automatic air pump the mixture will vary slightly with the r.p.m., but there is no occasion to readjust the mixture, as the engine will recover itself as soon as it regains normal flight. In the case of a normal climb of long duration it is advisable to readjust the mixture by the regulating valve, so that the engine is constantly developing its maximum speed. This readjustment is usually a slight closing of the regulating valve.

DESCENTS

Descents are made by three methods: First, by switching the engine off and on, as is usually done in the descents of short duration, or near the ground; second, by throttling the engine by closing the gasoline regulating valve; third, by stopping the engine, in which case the gasoline supply should be shut off by the regulating valve, but the switch should be left on to prevent, as far as possible the fouling of the spark plugs with lubricating oil.

REGULATING GASOLINE FOR RAPID FLIGHT

As the regulating valve is opened up the speed of the engine will increase to a certain point, after which it will not respond to the increased fuel supply, and finally, where the engine speed will decrease, due to an excess of fuel.

The best regulation for rapid flight is that which gives a maximum number of revolutions on the indicator, with the minimum opening of the regulator valve. So that after the valve has been slowly opened until the engine fails to respond further it is then wholly closed down until the engine speed shows signs of dropping. This position of the regulating valve handle for maximum power should be clearly marked so that it can be easily and quickly found.

LONG-DISTANCE FLIGHTS

The position of the regulating valve for maximum engine power is not the best when economy of fuel is important consideration. For a long-distance flight, or when it is necessary to remain in the air for a long period, the engine should be run at its most economical speed and load. This position will be indicated when the propeller in horizontal flight has attained about 85 per cent. of the maximum revolutions before mentioned. If, for example, the maximum revolutions on a certain machine for rapid flight has been found to be 1220 r.p.m., then the most economical speed will be 85 per cent. of this, or 1037 r.p.m.

Adjust the regulating valve in horizontal flight until this speed of 1037 r.p.m. is attained and mark the position of the valve handle so that for prolonged flight, this position can be quickly found. Atmospheric conditions may effect these regulating positions to some extent, but only very slightly.

STORAGE OF THE GNOME ENGINE

When an engine has to be stored it is recommended that the following points be carefully noted:

1. Remove any accumulation of oil in the cylinders.

2. Detach ball ends from cup ends by releasing circlips or release the fourth end pin from the levers and let all valves close. Tie down the valve cage with cloth or oily paper to prevent dust getting into the cylinders.

4. Tie down all connections to oil pump and air compressors with cloth or oily paper in the same manner.

5. Cover the rear end of crankshaft with dust cap.

6. Cover the three unions for oil and fuel with dust caps.

7. Close pointed end of nose with plug provided for that purpose.

8. Remove ignition plugs and close up the plug holes with old spark plugs or pieces of hardwood.

If the engine is to be shipped, the outside should be liberally coated with vaseline or similar substance to prevent rust. The valve or tappet rod after release, should be tied up securely at the loose end. String is preferable for this purpose.

When packing the engine in a case it should be mounted on a wooded tub at the bottom and securely stayed by cross timbers to prevent the slightest movement sideways.

Slots have been recently cut in the main bearer plate to allow the drawbars of the engine extractor to pass through. In case this has not been done on the engine you are handling it is advisable to do so as it greatly facilitates in removing of engine from the plane.

SECTION XIII

THE HISPANO-SUIZA ENGINE

This type of engine has proved very successful in actual work on the western front and is now being built in this country both for the French and American armies. As can be seen in Fig. 106, it is a V-type engine but has several peculiarities of design which

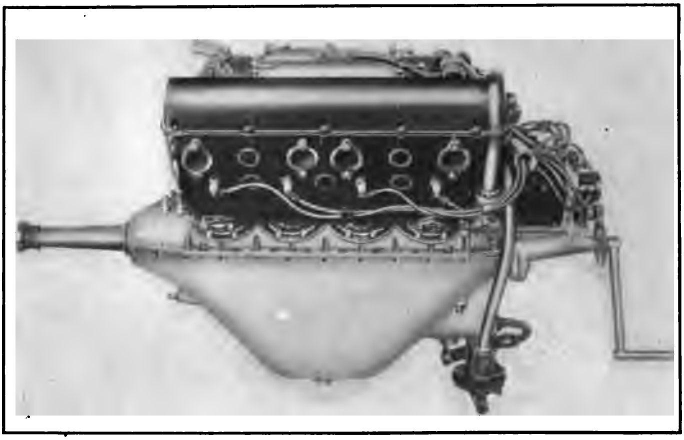


Fig. 106.—Hispano-Suiza engine.

make it different from any other. The cylinders are steel sleeves made from pierced forgings similar to high explosive and shrapnel shells. These are solid at the upper end and the valve seats are formed directly in the bottom of the cylinder itself. The outside of the cylinder is threaded and screws into the aluminum casting which looks like a cylinder block but is in reality only the water jackets for all four cylinders of the block. The lower end of the cylinder projects and has a flange by which the cylinder block is fastened to the engine base by means of studs.

There is an overhead camshaft with liberal sized cams which act directly on the top of adjustable caps over the valve stems. Instructions for setting up and handling the engine follow.

The Simplex, Model "A," Hispano-Suiza aeronautic engine is of the eight-cylinder "V" type, water-cooled, approximately $4\frac{3}{4} \times 5\frac{1}{8}$ inch bore and stroke, and develops 150 horsepower at 1450 r.p.m. at sea level. There are two cylinder blocks, each containing four cylinders, their center lines making an angle of 90 degrees between them. The individual cylinders are steel forgings, heat-treated, machined and threaded on the outside. These steel sleeves are flanged at the bottom and closed at the top, this surface being flat, providing for the two valve seats. The cylinders are screwed into the cast aluminum cylinder blocks which comprise the water jackets and valve ports, intake and exhaust passages. Each block, after cylinders and other parts are assembled, is given several coats of enamel, both inside and out, each coat being baked on. The coats on the inside are applied under pressure.

The pistons are aluminum castings, ribbed, and provided with four narrow rings at the top in two grooves and one oil ring near the bottom. The hollow case-hardened alloy steel piston pins are held in the pistons by a single long set screw passing completely through one end.

The connecting rods are of tubular section; the material heat-treated alloy steel. One rod turns directly on the crank pin while the other, which is forked, turns on the outside of the extended part of the former. The upper ends of the connecting rods are provided with bronze bushings.

The crankshaft is of chrome nickel steel of the four-throw type, 180 degrees between throws, machined all over. There are four plain main bearings bronze backed and babbitt lined and one annular ball main bearing at the rear (cranking) end. The thrust for either a tractor or propeller screw is provided for by a double row ball thrust bearing located in the front of the crankcase. The crankshaft is provided with a conical seat with key for the propeller hub and is bored hollow for lightness and for the oiling system.

The valves are set vertically in the cylinders along the center of each block and are directly operated by a single cam-shaft located over the valves. They are of Tungsten steel, with large diameter hollow stems, working in tight fitting cast-iron bushings, provided at the upper ends with case-hardened flat-headed adjusting discs, upon which the cams operate and are held to their seats by two concentric helical springs each, either one of which is sufficient, in case of breakage to the other, to insure the valves seating properly.

The hollow camshafts are mounted in three plain bronze bearings each and driven from the crankshaft by two vertical shafts and bevel gears of hardened alloy steel running in plain bronze bearings. These shafts are protected by housings of light steel tubing and each one is provided with a screw driver type of joint near the middle, allowing of ready removal of the cylinder blocks without dismounting other parts. The camshafts, cams and heads of the valve stems are all enclosed in oil tight cast aluminum removable housings. The camshaft is driven by conical gears.

The oiling of the engine is provided for by a positive pressure system, a sliding vane eccentric type of pump being mounted vertically directly below the crankshaft in the lower half of the crankcase and driven by the same bevel gear that drives the camshaft drive shafts. This pump takes oil through a pipe cast integral with the lower crankcase, forces it through a filter also cast in the case and provided with a removable screen; and then through other steel tubes cast in the case to three of the main *bearings.* From these bearings the oil enters the hollow crankshaft and is distributed to the four crank pins, proper oil holes and grooves being provided in the inner connecting rods to distribute the oil where needed. The lubrication of the cylinders and of the piston pins is provided for by oil thrown off from the rapidly revolving crankshaft. The fourth main bearing is also provided with an oil lead from the system, which takes care of the lubrication of this bearing, and through tubes running up the end of each cylinder block, provides oil for the camshafts. As the camshafts are hollow the oil is forced into them at one end through one of the bearings. Lubrication of the cams is provided by a small hole in each cam, and of the remaining bearings by other small holes. The excess of oil escapes through the other end of the camshaft in the form of a stream and oils the driving gears before it returns to the crankcase.

Ignition is furnished by two eight-cylinder magnetos firing two spark plugs per cylinder. One magneto is driven from each of the two vertical shafts by small bevel pinions meshing in bevel gears mounted directly on the magneto shafts.

All engines used in Sea-planes or planes of the pusher type are equipped with a geared-down hand crank starting device, and when thus equipped are geared up to a small starting magneto which gives a very hot spark at low engine speeds.

ADJUSTMENTS

Valve Clearances.—The clearance between the valve discs and the cams should be 2 millimeters (.0787 inch). It is important to check this clearance from time to time—and correct it if it varies, using the special wrench and the gage supplied for that purpose in the equipment.

Valve Timing.—In case it is necessary to demount the camshafts or the gears, the following is the method to use in order to determine the opening and closing positions of the valves.

First. Determine, as indicated above, the clearance between the cams and valve discs.

Second. Mount on the taper of the crankshaft a disc 360 millimeters (14.1734 inches) diameter. If this is not available, mark the timing on the propeller hub itself, which has a diameter of 180 millimeters (7.0867 inches).

Third. Place between the axis of the cylinder groups an arrow which will coincide with the rim of the disc or the propeller hub.

Fourth. On the face of the timing disc or hub flange, mark the top and bottom center, with regard to the arrow, and from these marks lay off the distances as indicated in the timing diagram, so that these lines correspond exactly to the motor timing.

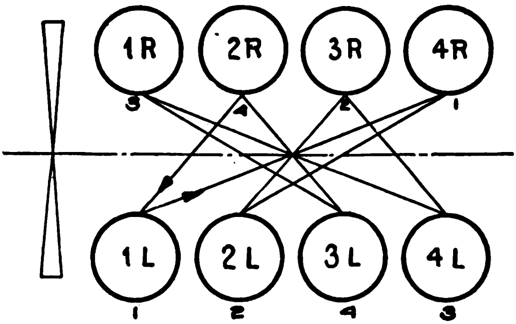


Fig. 107.—Timing diagram.

When the adjustment of one set is finished, the same procedure should be applied for the other, but taking account of the firing and timing which is in the following order:

1L–4R–2L–3R–4L–1R–3L–2R

For example: We know that cylinder 4R (4 right) intakes after 1L (1 left); hence we begin again with the intake opening of 1L and by turning the crankshaft 90 degrees (¼ revolution) in the direction of rotation, we have determined the opening of intake valve of cylinder 4R.

TIMING DIAGRAM

Timing	Length of arc taken in diameters of 360 m/m (14.1734 inches)	of 180 m/m (7.0867 inches)[1]
Intake opens	32 m/m (1.2599 inches)	16 after U.D.C.
Intake closes	165 m/m (6.4962 inches)	83 after L.D.C.
Exhaust opens	150 m/m (5.9056 inches)	75 before L.D.C.
Exhaust closes	32 m/m (1.2599 inches)	16 after U.D.C.
Spark Advance	64 m/m (2.5197 inches)	32 before U.D.C.

TIMING OF MAGNETOS

First. Mark the points of maximum advance, as indicated on the timing diagram, on the face of the 360 millimeters (14.1734 inches) timing disc or on the propeller hub flange.

Second. Turn the crankshaft of the engine until the cylinder 1L is nearing the end of the compression stroke, and the spark advance line on the disc coincides with the timing arrow.

Third. Turn the magneto shaft until the distributor brush touches the distributor segment, which is marked for Cylinder 1L and bolt down magneto.

Fourth. Loosen the three small bolts which hold the magneto gear to the disc and turn the disc until the platinum points of the circuit breaker just begin to separate. (Use cigarette paper between the points for timing.) Then tighten the bolts.

The two magnetos should be timed in exactly the same manner, and if one or the other of the magnetos is cut out while the engine is running, the number of revolutions of the engine lost should be the same (about 20).

Spark Plug Connections.—The distributor diagram facilitates the connection of spark plug wires.

[1] 180 m/m (7.0867 inches) is the diameter of the propeller flange.

All spark plugs located on the intake side of the cylinders are wired to the R. H. Magneto, while the plugs located on the exhaust side are wired to the L. H. magneto. If there is any misfiring, this arrangement makes it very easy to find which side has the bad spark plug.

OPERATION

Running the Engine.—Never "load" the engine immediately after starting it. Particularly in winter, allow it to operate at partly closed throttle or about 800 r.p.m.

In very cold weather, we advise stopping it after three or four minutes' operation and waiting a little time until the heat com-

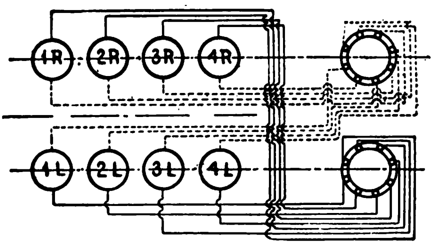


FIG. 108.—Wiring diagram.

municates to all parts of the crankcase, in order to render the oil thinner.

The engine is controlled by gas throttle, and is found to start best with a very small opening. The throttle lever should be about 3/16 inch from the stop screw. The second control is designed to correct the variations in carburetion required at the different altitudes where the engine is to operate.

One should determine a fixed point, before each start, of the best position for the altitude control (that which corresponds to the greatest number of revolutions). That position generally is satisfactory up to 1000 meters (3280 feet). Above that, it is necessary to make corrections, always of course, determined by the revolution counter.

Starting the Engine.—It is best to prime the engine through the petcocks on the intake pipes when starting the engine cold. If the engine is warm, no priming should be used. The choke valve of the carbureter should be raised as far as possible, and with the carbureter flooded and set as before referred to for starting, the engine should then be turned over at least two complete revolutions, the choke set back in the normal position again, and the engine will then be ready to start off. Never prime the engine when it is warm.

LUBRICATION

Notice.—If, in starting a new engine which is being run without an oil radiator, the oil pressure does not register, make sure that the end of the oil pump suction pipe is not closed with a brass plug. This can be examined by removing plug in the bottom of the lower half of the crankcase.

Before each start, be sure of the level of the oil in the crankcase with the aid of the gage plugs placed for this purpose in the sump.

The normal level corresponds to the height of the second plug, giving about 10 liters (2.64 gallons) in the case.

The oiling of all parts of the engine is automatic, under pressure. The magnetos need several drops of oil in the oil feed every 20 hours.

A good lubricating oil or some good grade of castor oil is recommended.

MAINTENANCE

After five hours running the distributor blocks of the magnetos should be cleaned to avoid any skipping or missing in their operation. The brushes of the high tension distributor should be oiled, preferably with lubricating oil; likewise the path of the ...es in the distributor block should have a coating of oil. ...nts the scattering of carbon dust in the distributor ...ch causes short circuiting or firing in the wrong

After ten hours running and before each important flight:

Clean the spark plugs (with alcohol if they are greasy from castor oil), the magneto distributors, and the oil filter.

Every twenty hours clean the gasoline strainer and the water filters.

Every fifty hours clean out the combustion chambers after the cylinders have been taken off; grind the valves. Never unscrew the cylinders from the water jacket. After reassembly, be sure that the timing is correct.

PRECAUTIONS TO TAKE UNDER FREEZING CONDITIONS

The circulating water can be kept from freezing by adding 25 per cent. of glycerine. Without that precaution, it is necessary to drain the water each night.

In order to facilitate starting in the morning and freeing (ungumming) the rings, we advise giving, while the engine is still hot, after the previous run, several shots of kerosene through the petcocks of the inlet manifolds and turning the propeller over several times.

RECOMMENDATIONS FOR ATTACHING PROPELLERS

Always put the keyway of the hub in the axis of the blades. Starting the engine by cranking the propeller is facilitated if the propeller is keyed in that position which is the most favorable for "carrying over compression." More than that, this position has been adopted for adjustment of the layout for firing the machine gun through the propeller. That recommendation, then, becomes very important.

The mounting of the hub on the taper of the crankshaft requires very particular precautions; the hub supplied with each engine has been fitted to its taper—do not omit that operation in case of replacement of the hub.

Before mounting be sure that the parts fit perfectly and are lubricated with tallow or oil and graphite. A bad fit rapidly develops play and, if run in this condition, will do great damage.

A faulty balance of the propeller always causes vibration. As soon as one encounters this condition, correct the balance with care and also the pitch (because it happens that wood warps).

RECOMMENDATIONS FOR INSTALLING THE ENGINE IN AIRPLANES

The engine should be anchored on a rigid support which must be straight and smooth, where the engine is fastened on, and should be lined with fiber.

Housing-in of the Engine.—Whenever possible the camshaft housing covers should be left exposed; their disassembly is then very easy and this arrangement permits the constructor to cut down the size of the cowls. If, in certain cases, the engine is mounted without any cowls, some method of sheltering the magnetos should be provided for.

PARTS TO WHICH EASY ACCESS AND EASY TAKE-DOWN IS DESIRABLE

Magnetos—spark plugs—oil level plugs—oil filters—crank case breather tube cap.

Carbureter.—Air should be taken in the outside by a leak-proof tube and made with a minimum inside diameter of 90 millimeters (3.5434 inches). At the lower part of the carbureter is a nipple, to which a small tube should be fastened, which lets the gasoline run off, this tube discharging far enough to rear under the airplanes (as far away from the exhaust as possible).

In addition to the throttle valve controlling the speed of the engine, there is also installed in the pilot's cock-pit another control operating the altitude corrective mechanism of the carbureter.

There should be also, as close to the engine as possible, a cock enabling the pilot to shut off the gasoline supply.

Water Circulation.—It is important in any case, that there be a sufficient head of water above the highest part of the cylinder water space. This head should never go below 30 centimeters (11.811 inches); when two side radiators are used they should be joined, if possible, by a communicating tube on top. The circulating system should have at its highest point a small expansion

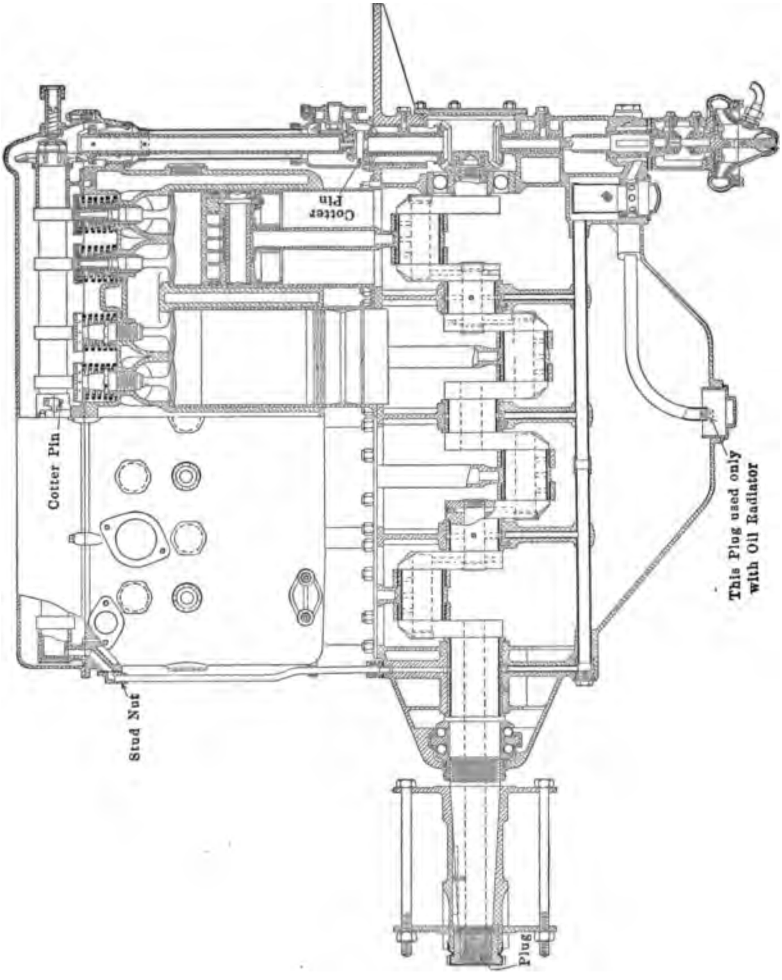


FIG. 109.—Section of Hispano-Suiza.

tank with a level cock, which avoids complete refilling of the tank. The space in the tank above the level cock should not have less than 3 liters (3 quarts) capacity, to allow for the expansion of the water. It is indispensable to locate, in an accessible manner, a filter between the cylinder outlets and each radiator to stop sediment in the water which deposits in the jackets and tends to clog the radiators.

The delivery of the water pump is in the neighborhood of 100 liters (26.41 gallons) per minute at 1400 r.p.m. The difference between the inlet and outlet temperature of the water is about 10 degrees Centigrade (20 degrees Fahrenheit.)

Oil Tank and Cooling of Oil.—If the engine is mounted on a machine intended to make flights of more than three hours, it will be necessary to install an oil reservoir (allowing 2 liters (2 quarts) of oil used per hour).

This tank may be used as an oil cooling radiator.

In this case, the suction pipe in the pump must, of necessity, be plugged. (A brass plug, which is furnished, may be screwed into the tapped end of the oil intake by removing the sump drain plug.)

Connect the bottom of the oil radiator by a pipe to one or the other of the oil plugs located in the rear of the crankcase, on the intake side of the oil pump. The return to the radiator is made by a pipe joined to the sump drain plug.

These suction and delivery oil pipes should have an inside diameter of 14 millimeters (.5512 inch) for the suction pipe and 28 millimeters (1.1024 inches) for the return; the radiator tubes at least 10 millimeters (.3937 inch) inside diameter.

It is always necessary to equip the top part of the reservoir with a plug for the release of air when refilling.

COMPLETE DISASSEMBLY

Place the engine on a suitable stand, and proceed as follows:

First. **Demounting the Carbureter.**—Back off the union nut of the detachable flanged inlet pipe and the four nuts supporting the intake manifold tee and lift it off with the carbureter.

Take off the inlet manifolds by unscrewing the eight nuts on the water jacket castings.

Second. Take off the breather pipe, the revolution counter drive, the spark plug wires and manifold, and the spark plugs.

Third. **Dismounting the Water Pump.**—Unscrew the hose clamps on the rubber connections of the water pipes. Remove the nuts fastening the water pipe flanges to the aluminum water jackets and take off the water pipes. Unscrew the union holding the small copper pipe to the water pump and remove pipe. Unscrew the 2 nuts and lower the complete water pump.

Fourth. **Removing Magnetos.**—Loosen the packing nut of the magneto drive gear housing. Unscrew the nuts holding the housing and magneto holding screws. Take off the magnetos with their gears by raising magnetos to disengage the centering dowels.

Fifth.. **Taking off the Cylinder Blocks.**—Take off the oil pipes to the cylinder block by unscrewing the unions and the nuts attaching the flanges to the cylinder jackets. Unscrew the nuts bolting the cylinders to the upper crankcase, except one nut on the inside of each group. Turn the crankshaft so that the pistons of cylinders 1 and 4 of the left hand cylinder block are on top. Take off the remaining nut and lift off the left block, being careful to support the pistons. The same operation holds good for the right hand cylinder block.

Sixth. **Removing Pistons.**—Unscrew the wrist pin set screws of pistons 1L, 4L, 1R and 4R, after having removed split cotters (do not forget to turn the slot of the oil ring to register with the cotter hole). Take off the pistons by driving out the wrist pins from front to rear for the left and from rear to front for the right side of the motor. Turn the crankshaft a half revolution and proceed as before with pistons 2L, 3L, 2R and 3R.

Caution.—Never remove the cylinder sleeves from the aluminum water jackets.

Seventh. **Taking Down the Crankcase.**—Unscrew the nuts of the bearing studs, both upper and lower. Invert the crankcase and take off the nuts and bolts holding the two halves together. Remove starting crank housing, if any, or the cover plate on the magneto end of crankcase. Loosen up the joint (of the case) with a piece of wood, and lift off the lower half and avoid letting the oil pump driving gear fall. Take off the lower half of the main bearings of the crankshaft.

Eighth. **Removing Connecting Rods.**—Extract the cotter-pins of the bolts of the forked connecting rods, unscrew the nuts and remove the rods. Unlock the cap screws of the inner rods (be careful not to injure the babbitt on the exterior of the rod) and take off the connecting rods after having removed the cap screws.

Ninth. **Removing Oil Pump.**—Unscrew the four nuts and remove the water pump bracket which also serves as the oil pump cover. Drive out the oil pump, with the aid of a piece of wood or copper, through the driving pinion bearing hole after the pinion is removed.

Tenth. **Removing the Camshaft.**—Remove the cotter pins of the nuts of the bearing holding down bolts; unscrew these nuts and take off the shaft with its three bearings.

Eleventh. **Removing Valves.**—Mount the cylinder block on the cradle of a special assembly stand. Put into the cylinder four pieces of wood somewhat longer than the inside of the cylinders and held together by a cross piece attached to the cylinders.

Anchor the hooked valve tool to the studs of the exhaust flanges and take off each valve in the following manner:

Place the hollow yoke of the lever on top of the valve tappet washer and press down the lever until the serrated washer unlocks the adjusting screw.

Unscrew the mushroom with the other hand until the springs are no longer compressed. Dispense with the lever (tool) and finish unscrewing the mushrooms. Remove the retainers and the springs. When that operation is finished for the eight valves, remove the pieces of wood and take out the valves.

DISASSEMBLY OF UNITS

Unscrew the four nuts bolting the pump to the crankcase and remove, successively, the cover and the pump spindle with the impeller. Introduce an elbowed tool, square on end, and preferably of copper, in the upper bore of the pump body, above which it can be grappled; then pull down on the stem to remove the body of the pump.

Removing the Lower Half of the Crankcase for Summary Inspection of Connecting Rods.—Remove the carbureter and its connections and plug the inlet passages to the tee, to eliminate the possibility of foreign substances getting in. Take off the cover plate at the end of the crankshaft or the starting crank mechanism. Remove the water pump and plug hole to prevent the entrance of dirt and dust. Unscrew the nuts of the bearing studs, and, very carefully, turn the engine bottom side up, letting it rest on the camshaft housings. Unscrew the nuts of the crankcase studs and bolts, and take off the lower half after having pried the joint apart with a piece of wood. If one wishes to rotate the crankshaft, take out the spark plugs on the exhaust side and hold the rear ball races in place with a wood flange drilled with two holes corresponding to the two stud bolts of the bearing.

The tools used are shown in Fig. 110.

REASSEMBLY

All frictional surfaces should be covered with oil as they are put together.

The references are always taken in relation to the front of the engine. (Tapered end of crankshaft.)

The inner connecting rods are used on the left group of cylinders, the forked rods operating in the right group. Without any compression, it should be possible to turn the engine over by hand on reassembly, by means of the propeller flange.

Attaching the Oil Pump.—The bolts attaching the pump to the crankcase are so made that the oil pump cannot be improperly *mounted*. This being in place, be sure that [illegible] freely by hand after having put the driving pinion in place. Place paper gasket between the bracket and the oil pump housing, and be sure to put one hole in the gasket, so that the oil which leaks by the shaft into the little oil pocket can be sucked back into the oil pump.

Mounting the Water Pump.—Fasten the water pump and be sure, as before, that the spindle turns by hand through the agency of the driving pinion. The stuffing box of the oil pump should be very lightly tightened up.

Assembling the Connecting Rods.—Assembly of the connecting rods can be made with the top half of the crankcase inverted, but it is preferable to do it at the work-bench, the crankshaft ends

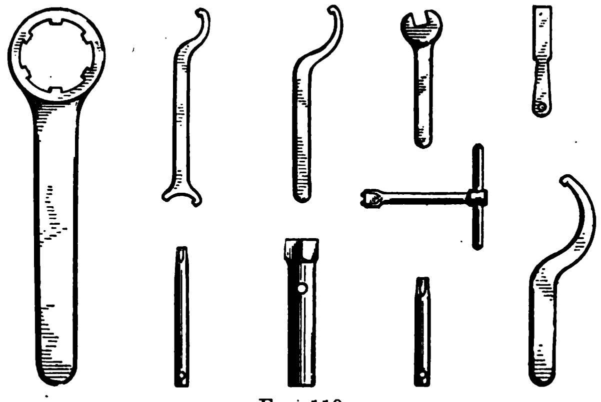


FIG. 110.

being held in a wood-collar. Fit and lock the 4 inner connecting rods in place, then the 4 forked rods, being sure that the cotter pins of the inner connecting rod cap screws do not interfere in the clearances of the outer rods. Cotter pins in connecting rods should fit tight.

Assembly of the Crankcase.—The top half of the crankcase being inverted, on the assembly stand, put the top half of the

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hand after having put the driving pinion in place. Place paper gasket between the bracket and the oil pump housing, and be sure to put one hole in the gasket, so that the oil which leaks by the shaft into the little oil pocket can be sucked back into the oil pump.

Mounting the Water Pump.—Fasten the water pump and be sure, as before, that the spindle turns by hand through the agency of the driving pinion. The stuffing box of the oil pump should be very lightly tightened up.

Assembling the Connecting Rods.—Assembly of the connecting rods can be made with the top half of the crankcase inverted, but it is preferable to do it at the work-bench, the crankshaft ends

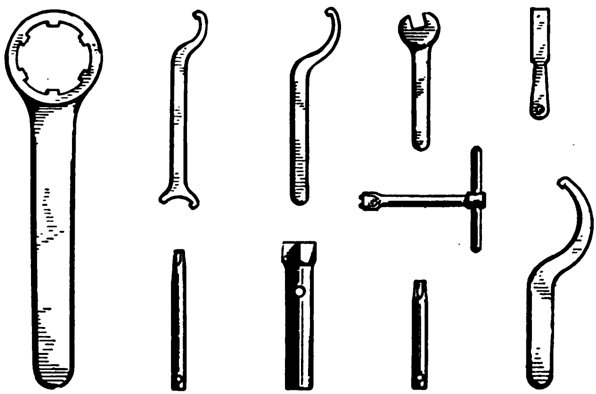

Fig. 110.

being held in a wood-collar. Fit and lock the 4 inner connecting rods in place, then the 4 forked rods, being sure that the cotter pins of the inner connecting rod cap screws do not interfere in the clearances of the outer rods. Cotter pins in connecting rods should fit tight.

Assembly of the Crankcase.—The top half of the crankcase being inverted, on the assembly stand, put the top half of the main bearings in place, mount the crankshaft in the upper half of the case, observing the following references:

Put the half bearings on the lower crankcase in place.

Apply a light coat of shellac to the faces of the crankcase halves, allow it to "set" several minutes and then put the lower half in place, holding the oil pump driving gear to keep it from falling out.

Screw up the nuts on the assembly bolts and studs and the nuts of the two studs of the rear bearing; turn the engine over and screw up the main bearing stud-bolt nuts.

Bolt the crankcase down to the assembly stand with at least two bolts.

Fitting the Pistons.—The half circular grooves carrying the oil to the piston wrist-pins should always be turned toward the inside of the engine. Drive in place all the wrist-pins of the left cylinder group from rear to front, and from front to rear for the right group.

Mount the timing disc on the crankshaft taper and rotate the crankshaft one-eighth revolution in the direction of rotation, in order to bring the throws vertical and fit pistons 1L, 4L, 1R and 4R. Rotate a half turn in the same direction and fit 4 pistons 2L, 3L, 2R and 3R.

Be sure that the heads of the cotter pins for the wrist-pin set screws do not project above the bottom of the annular groove. It is recommended that the heads of the cotters be lightly peened to the diameter of the countersink of the holes.

Assembling Valves.—Proceed in the opposite manner to disassembling.

Assembling the Cylinder Blocks.—Rotate the crankshaft an eighth of a revolution, always in the direction of rotation, in order to bring the 4 pistons of group L to the same height. Tip the assembly stand to bring the pistons of this group vertical, attach ᵗhe magneto drive housing and its stuffing box nut on the tubular using, before putting the cylinder block in place. Turn the ton rings so that the joints are 180 degrees apart. (The slots ould be alternately left and right.)

Take the piston ring jig shown above, an aluminum contracting ring, and compress the rings, then gently put the cylinder block in place, which being aligned, will go down of its own weight, the register of the jaw clutch of the vertical shaft with the dogs of the driving gear being in line. Remove the ring jig when all the rings are recessed in the cylinders. Screw down the nuts of the cylinder studs of the left cylinder block; tip the stand in the opposite direction, turn the crankshaft a quarter of a turn, always in the direction of rotation, and go through the same procedure for the right group of cylinders.

Attaching the Camshaft.—Readjust the assembly stand to its vertical position. Assemble the camshafts according to the reference marks. Draw up and pin the nuts on the bearing studs and adjust the clearance between the cams and the valve adjusting mushroom.

Mounting of Magnetos.—Fasten the timing arrow, under the nuts of the forward bearing studs, and proceed timing the magnetos as described under paragraph "Magnetos."

Adjust the Timing.—After reassembly it is necessary to retime the engine. The engine being at upper dead center of cylinder 1L, and the timing disc mounted on the taper, turn the engine shaft 32 milimeters forward (position where the inlet opens and the exhaust closes of cylinder 1L) and put the camshaft in place, the closing of the exhaust cam and opening of the inlet valve cam making the same angle in relation to the valve adjustment mushrooms of the first cylinder, 1L. Tighten the nuts on the three bearings and adjust the valve clearance to 2 millimeters. Bring the disc slowly backward (turn the crankshaft in the opposite direction), then gently rotate forward, feeling the exhaust valve which should close 32 millimeters after dead center, while at the same time the inlet valve should begin to unseat.

If the timing is not accurate, it is necessary to take the gear off for the sake of shifting the collar key on the camshaft, or in turning the vertical shaft a half revolution, to give the foll

To give the advance, rotate the gear on the shaft to the right, and to the left for retard.

On the 360 millimeters disc:

1 tooth (of the gear) gives 62.82 millimeters.

½ turn of the vertical shaft and ½ tooth of the gear gives 31.41 millimeters.

1 key-way, ⅕ tooth, gives 12.56 millimeters.

3 key-ways and ½ turn of the vertical shaft, 1/10 tooth, gives 6.28 millimeters.

When the adjustment of the L group is finished, proceed similarly for the right group. The intake opening of the fourth cylinder, right block, should begin ¼ of a revolution of the motor shaft after the intake of 1L cylinder.

SECTION XIV

THE UNITED STATES STANDARD AVIATION ENGINE OR "LIBERTY" ENGINE

This engine is very largely the work of Messrs. Vincent and Hall, the former of the Packard Motor Co. and the latter of the Hall-Scott Motor Co. Many other engineers contributed to the general fund of knowledge and the best practice both at home and abroad was consulted and carefully considered. There is nothing radically new in the design except as pertains to its manufacturing possibilities, and here we have the advantages of the automobile development, which has been utilized to its fullest extent.

It is not permissible to print details of the new engine at this time but it can be described in a general way as having steel cylinders made from hollow forgings, with sheet-metal water jackets welded in place. In fact autogenous welding plays an important part in its construction and makes possible a much lighter engine than would otherwise be possible.

Every part has been designed with a view of easy manufacture and as a result it has separate valve cages which are afterward welded in place, water jackets which can be stamped out in the punch press and rapidly assembled and welded in position, and all details have been worked out with the view of rapid manufacture and maximum service.

The engine develops approximately 30 horsepower per cylinder and the cylinders are standard for all sizes of engine. They can be combined in any way desired on engine bases for four, six, eight or twelve cylinders according to the amount of power desired. The weight is about 2 pounds per horsepower in the larger sizes. The ignition system is something of a departure from current practice, but is in duplicate so that either unit can fire all of the cylinders. Each cylinder has two spark plugs which are always available.

No special instructions are available at this time.

SECTION XV

TABLE OF CHARACTERISTICS OF AMERICAN AIRPLANE ENGINES

Maker's name and model	Number of cylinders	Bore (inches)	Stroke (inches)	Piston displacement (cubic inches)	Hp.	R.p.m.	Weight of engine with carbureter and ignition	Weight per horsepower, pounds
Aëromarine	6	4½	5⅛	449.00	85	1,400	440	5.20
Curtiss OX	8	4	5	502.60	90	1,400	375	4.17
Curtiss OXX-2	8	4¼	5	567.50	100	1,400	423	4.23
Curtiss V-2	8	5	7	1,100.00	200	1,400	690	3.45
Duesenberg A-4	4	4¾	7	496.00	140	2,100	455	3.25
Duesenberg V-12	12	4¾	7	1,488.00	250	1,800	923	3.68
General Ordnance Type L.M.	8	4¾	6½	920.00	200	....	876¼	4.38
General Vehicle Gnome Mono.	9	4.33	5.9	848.00	100	1,200	272	2.72
Gyro K	7	4½	6	......	90	1,250	215	2.20
Gyro L	9	4½	6	859.00	100	1,200	285	2.85
Hall-Scott A-7	4	5	7	550.00	90–100	1,400	410	4.10
Hall-Scott A-5	6	5	7	825.00	125	1,300	592	4.62

TABLE OF CHARACTERISTICS OF AMERICAN AIRPLANE ENGINES.—(*Continued*)

Maker's name and model	Number of cylinders	Bore (inches)	Stroke (inches)	Piston displacement (cubic inches)	Hp.	R.p.m.	Weight of engine with carbureter and ignition	Weight per horsepower, pounds
Hispano Suiza....................	8	$4\frac{5}{8}$	5	672.00	154	1,500	455	2.95
Knox Motors Co.................	12	$4\frac{3}{4}$	7	1,555.00	300	1,800	1,425	4.75
Maximotor A-6..................	6	$4\frac{1}{2}$	5	477.00	85	1,600	340	....
Maximotor B-6..................	6	5	6	706.80	115	1,600	385	....
Maximotor A-8..................	8	$4\frac{1}{2}$	5	636.00	115	1,600	420	....
Sturtevant 5.....................	8	4	$5\frac{1}{2}$	522.90	140	2,000	580	4.15
Sturtevant 5-A..................	8	4	$5\frac{1}{2}$	......	140	2,000	514	3.68
Thomas 8........................	8	4	$5\frac{1}{2}$	552.90	135	2,000	630 with self-starter	4.62
Thomas 88.......................	8	$4\frac{1}{8}$	$5\frac{1}{2}$	552.90	150	2,100	525 lb. with self-starter	3.50
Wisconsin........................	6	5	$6\frac{1}{2}$	765.70	140	1,380	637	4.55
Wisconsin........................	12	5	$6\frac{1}{2}$	15.32	250	1,200	....	....

SECTION XVI

NOTES AND INSTRUCTIONS TO GOVERNMENT INSPECTORS OF AIRPLANES AND AIRPLANE ENGINES

These instructions are those furnished to inspectors of airplanes for Government service. It will prove helpful to all who have to do with airplane work and gives many useful suggestions. The illustrations showing the checking up of propeller dimensions need little explanation. Fig. 111 shows a checking plate

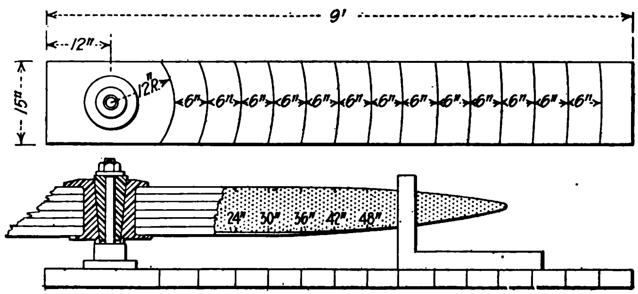

Fig. 111.—Checking plate for propellers.

on which the propeller is mounted by its hub and with graduations every 6 inches so as to make it easy to check the propeller at uniform points. The square transfers the points on the plate to the propeller itself. Fig. 112 shows a cross-section of the plate and the propellers being measured and contains all necessary information. The two scales on each side are graduated in hundredths of an inch for accurate height readings when the straight-edge is laid across the chord of the propeller blade, as shown. Fig. 113 shows a special protractor for reading the angle at any desired point, the pitch being obtained from the chart, Fig. 114. Figs. 115 and 116 give blank forms for keeping a record of the propellers.

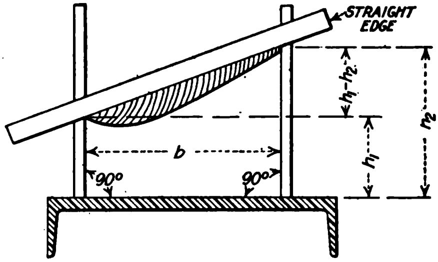

FIG. 112.—Measuring propeller blade.

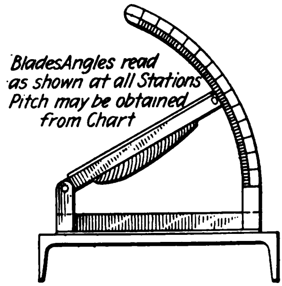

FIG. 113.—Protractor for propeller.

DUTIES OF INSPECTORS OF AIRPLANES AND AIRPLANE ENGINES

An inspector is an authorized and responsible representative of the United States Government.

He will act for the Government in matters relating to the inspection and acceptance of material manufactured for the Government.

Reports as required will be made as to:

1. Progress of manufacture.
2. Material accepted.
3. Material rejected.
4. Material shipped.

He will accept only such material as satisfies the requirements.

He will determine beyond a doubt, where no specifications have been issued by the Government, that material for Government use will perform the function for which it is intended.

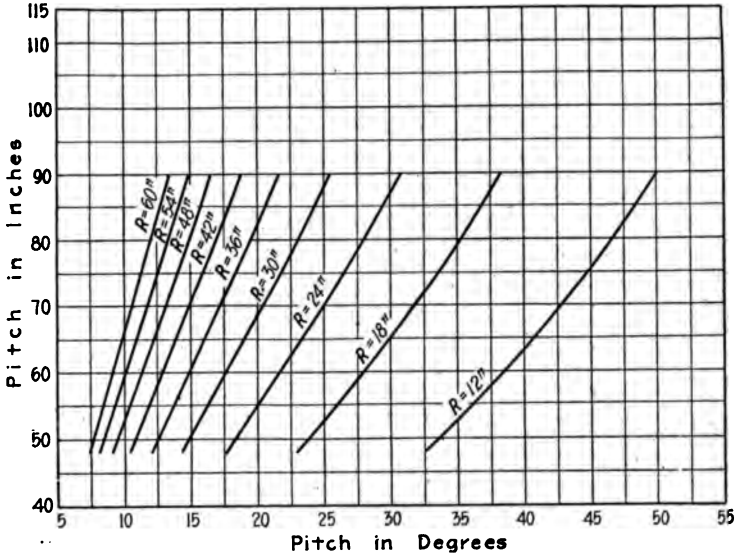

FIG. 114.—Chart for pitch of propeller.

DISTANCE FROM AXIS IN INCHES	ANGLE OF BLADES				ERROR IN ALIGNMENT OF BLADES				ERROR IN FIT OF BACK TEMPLATE				ERROR IN BLADE CONTOUR FROM PAPER PATTERN				PITCH IN INCHES FROM CHART			
	No. 1 Blade	No. 2 Blade	No. 3 Blade	No. 4 Blade	No. Blade	No. Blade	No. Blade	No. Blade	No. 1 Blade	No. 2 Blade	No. 3 Blade	No. 4 Blade	No. 1 Blade	No. 2 Blade	No. 3 Blade	No. 4 Blade	No. 1 Blade	No. 2 Blade	No. 3 Blade	No. 4 Blade
12"																				
18"																				
24"																				
30"																				
36"																				
42"																				
48"																				
54"																				
60"																				

FIG. 115.—Blank for propeller data.

Distance from axis in inches	Error in fit of back templates				Error in blade contour from paper pattern				Remarks											
	No. 1 Blade	No. 2 Blade	No. 3 Blade	No. 4 Blade	No. 1 Blade	No. 2 Blade	No. 3 Blade	No. 4 Blade												
12"																				
18"																				
24"																				
30"																				
36"																				
42"																				
48"																				
54"																				
60"																				

FIG. 116.—Blank for propeller data.

Distance from axis in inches	h_2 (See Sketch)				h_1 (See Sketch)				b (See Sketch)				Pitch in inches				Error of alignment in inches			
	No. 1 Blade	No. 2 Blade	No. 3 Blade	No. 4 Blade	No. 1 Blade	No. 2 Blade	No. 3 Blade	No. 4 Blade	No. 1 Blade	No. 2 Blade	No. 3 Blade	No. 4 Blade	No. 1 Blade	No. 2 Blade	No. 3 Blade	No. 4 Blade	No. 1 Blade	No. 2 Blade	No. 3 Blade	No. 4 Blade
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48"																				
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60"																				

FIG. 116a.—Blank for propeller data.

He will coöperate with other Government inspectors for the good of the service.

He will obey orders only when such orders emanate from a duly authorized source.

He will refer all matters upon which he feels that he is not qualified to act or to render a decision to the Chief Signal Officer of the Army, Washington, D. C. In many cases conditions may warrant use of the telegraph to expedite inspection and production. Inspectors should exercise initiative and assume responsibility in proportion to the exigencies of the service.

Inspectors will keep such records as will furnish a clear and complete history of any action taken.

Inspectors will call attention of the proper authority within a manufacturing organization to any points considered doubtful or objectionable. He will render constructive criticism which will aid in the correction of the difficulty.

Complete fulfillment of the trust imposed must be accomplished. Harsh and arbitrary methods in performance of duties must be avoided.

An inspector taking a new station will immediately upon arrival at the factory or station present himself in person to the highest representative of the organization there present. He will ascertain from that person the names of those persons with whom he shall have official dealings.

Inspectors will hold official communication or discuss matters relative to design only with the chief engineer, superintendent, foreman of the factory, or authorized person acting for them.

Matters of design must be considered as confidential and only imparted to the Government.

All criticisms of design and reports of serious defects of workmanship or material shall be made in writing to the properly authorized representative of the organization at fault.

All controversies as to inspection that cannot be settled between the factory management and Army inspector will be submitted to the Office of the Chief Signal Officer. All controversies reported to the Chief Signal Officer will set forth clearly and concisely the attitude of the manufacturer, as well as that of the inspector.

The senior inspector at any station will sign all reports or communications made to higher authorities or to the manufacturer. Other inspectors will report to the senior inspector and will be subject to orders from him.

Visiting inspectors assigned for temporary duty will report to the senior inspector at the station immediately upon arrival. He will coöperate with the senior inspector at all times. He will make his reports to the Office of the Chief Signal Officer and furnish copy of such reports to the senior inspector at the factory. He will hold communication with the manufacturer only through the senior inspector.

General Remarks on Inspection

Inspectors will bear in mind the fact that the Government specifies material of a definite quality and it is the duty of the inspector to make certain that material fully meets requirements.

Army inspectors will examine only such material as has been in some way clearly indicated as inspected by the manufacturers' inspectors.

No parts rejected by inspectors will be used in any assembly intended for Government use except by written authority from the Office of the Chief Signal Officer.

An inspector will exercise a general supervision over raw material received at the factory and likely to be used for the Government.

Following the production and acceptance of a machine of any type, complete working drawings will be furnished by the manufacturer to the inspector. All other machines of this type will be made in accordance therewith and no departures therefrom permitted without written authority from the Office of the Chief Signal Officer.

It is understood that the manufacturer may try out in the sample machine experimental features, but that in all other machines built under the same contract there will be no experimental design, material, or workmanship.

Material proved defective may be rejected at any time in the course of manufacture or assembly, even though having already been passed by an inspector.

It is understood that the manufacturer reserves the right to reject any material or parts already accepted by the Government inspector if such rejection is approved by the Government inspector.

Engine Tests

The question has arisen as to how thorough a retest of an engine should be in case of failure during the investigation test or the 6-hour test.

It is not desired to submit the manufacturer to unnecessary expense in this connection, but it is desired to ascertain beyond doubt whether or not the engine is really a serviceable engine for airplane usage.

As a general rule it is safe to state that the failure of any vital part should be followed by complete retest of engine. This is subject to modifications in accordance with the following illustrations:

Assume the failure of a valve spring. It is due to one of three things—design, material, or workmanship. It should be the duty of the inspector to discover by a practical method in which class this failure may be. If due to design it can be only determined by repeated tests. If any continuous test is interrupted by valve springs it is a suspicious circumstance, and the following procedure will probably discover whether it is due to design or material. Take other valve springs at random. Break them in any convenient manner. If the grain of the steel at the fracture is coarsely crystalline in all of them, then it is fair to presume that all the valve springs of the entire lot are defective and that the steel has been improperly heat-treated or tempered. If, on the other hand, the grain of the steel shows a fine grain fracture, characteristic of good valve spring steel, then it is probable that repeated failure is due to improper design. If the inspector finds that the springs are either faulty in design or material there is no use in calling for repeated tests until a new lot of springs is obtained.

If, on the other hand, the procedure shows a good grain spring steel, and in the opinion of the inspector the design is good, the failure was probably due to accidental causes and the springs may be replaced and the test continued without complete retest.

In cases of this kind, where the inspector is in doubt, samples of the broken part should be submitted to this office where analysis or further examination may be made to determine the real cause of the trouble.

In cases of failure of magneto, it may be due to the magneto itself, or to the magneto drive, which may transmit to the magneto stresses and shocks that should not be possible in connection with good engineering design.

Where the inspector feels that the design is at fault, he should so report and with his report submit detailed blue prints or sketches of conditions existing, if possible, and suggestions for improvements.

In case of failure of bearings, trouble may be due to lubricating system being designed wrong, or to accidental failure of it. The inspector should be able to discriminate and to know whether retest is necessary.

An engine with an improper lubricating system will fail repeatedly, and retest will be called for if the inspector suspects this cause of failure. If the failure is proven to be accidental, then only such a portion of retest should be demanded as inspector considers necessary.

It is not desirable to enumerate all details that may fail, but if failures are handled in the above-suggested manner, a reasonable conclusion should be possible and one that will at all times be fair to the manufacturer and at the same time protect the Government against all defective engines.

So far as possible in connection with engine tests, observations shall be taken in accordance with standards adopted by the Society of Automotive Engineers.

The following suggestions should be adhered to as closely as possible in reference to Specification 1002, Section No. 11, Investigation Test. These suggestions do not refer to final acceptance test, which will be covered later. The inspector or inspectors viewing the investigation test should bear in mind the fact that the engine to be tested is a finished product, and no vital parts will be allowed to be changed during the continuance of the run. The following adjustments will be considered permissible:

Gaskets may be replaced only once.

One complete set of spark plugs may be substituted.

Two valve springs may be replaced.

Water, oil, or gas leaks may be remedied.

Pumps may be adjusted.

Carbureters may be adjusted.

Magnetos may be adjusted.

Valve timing may be adjusted.

Other replacements will not be permissible during this or the Final Acceptance Test. Time required to make any of the above adjustments should be added to the total time of run.

Inspectors will submit detailed reports on such tests to this office, and it is suggested that they make frequent notations as to the test proceedings.

The following should receive close attention by inspectors during the Final Acceptance Test of 6 hours. (Re. Specification 1002, Sec. 11.) This test is to be given every engine built for the Government before being accepted by the Army inspectors. The entire test should be run at the maximum horsepower at rated revolutions per minute of the engine, and only such adjustments as are given under investigation tests will be permitted without an entirely new run of the engine.

When the engine is disassembled after this run the inspector should view every part liable to breakage or wear, and in case of excessive wear should insist on replacement of the part. When such replacement involves a vital part, such as a piston, bearing, cylinder, the engine should be returned to the stand and entire retest made over. After this retest the engine should be disassembled and inspected as before.

The final-hour test is to be made on every engine sold to the Government and on a suitable dynamometer. The engine should never develop less than 4 per cent. of its maximum horsepower at any time during the run. Inspectors should take their own readings and assure themselves that the engine is up to specifications in every detail. It is recommended that in addition the engine be run at 300 to 400 r.p.m. for at least 10 minutes and then the throttle to be opened quickly to ascertain if carbureter is adjusted properly and that all cylinders are firing at low engine speeds.

Inspection of Cylinders

1. Cylinder jackets should be tested for leaks while submerged in water with air pressure. Pressure to be at least twice that of normal water pressure.

2. Cylinder bore should be checked carefully at four points both top and

bottom, for being out of round, for being over or above tolerance in size, and for finish of bore.

3. Cylinder studs must be of proper height and square with surface.
4. Valve seats should be inspected for uniform width and location.
5. Valves after being ground to a gasoline tight seat should be inspected for leaks in three positions approximately 120 degrees apart without removing the gasoline from the cage.
6. Valve springs should be of specified strength and when compressed should not be compressed more than drawing limits.
7. All valve mechanism should be inspected for workmanship.
8. Intake manifolds are inspected internally and externally for workmanship; surfaces of manifold joints and valve cage joints must be true and of good surface. These surfaces should be checked on surface plate.

Inspection of Crank Case Upper Half

1. Check distances from center line of crankshaft to deck, both front and back, and between crankshaft and camshaft.
2. Check distances from each end of camshaft to top of deck, and on V-type engines to both decks.
3. Check cylinder centers, also bore of cylinder holes.
4. Check cam-follower guide holes for centers against camshaft cam centers.
5. Check thrust-bearing bore for size.
6. Check all studs for cotter-hole placement, alinement, threads, and all tapped holes for threads with plug gage.
7. Check camshaft bearing to main bearing for size, alinement, and condition of bore.
8. Check magneto-bearing bore for distance from camshaft and size.
9. Examine case for sand holes, gas holes, and defects such as shifting of cores.
10. Measure the thickness of all walls and decks.

Inspection of Crank Case Lower Half

1. Inspect lower case for center distances of oil and water pumps.
2. Inspect for oil leaks when filled with kerosene.
3. Joints of upper and lower case should be good fit.
4. Check location of gear cover holes and surfaces.

Inspection of Crankshafts

1. Stamp manufacturer's number and S. C. number on shaft.
2. Measure each bearing at four points 90 degrees apart.

3. Measure thrust bearing.
4. Measure gear bearings and seats.
5. Try taper and spline.
6. Propeller-hub thread.
7. Thrust-bearing thread.
8. Try bored hole for starter.
9. Try width of throws.
10. Try width of bearings.
11. Measure length dimensions.
12. Try oil holes for location and size.
13. Examine for checks and flaws.
14. Try bearings for run out.
15. Scleroscope test for quality of steel, usually about 40 to 52.
16. Inspect and measure taper with great care.
17. Inspect and measure spline or keys with great care.
18. Inspect and check threads with plug gage.
19. Examine running and standing balance.
20. Inspect holes and threads for oil system in shaft.
21. Make oil-pressure test for leaks in oil system.

Inspection of Camshaft

1. Camshafts should be tested for hardness by both Brinell and Scleroscope tests.

2. Shafts should be set up in centers and each cam tested for opening and closing points, neutral period, amount of opening, size and condition of bearing surfaces, and distance between cams.

3. Ground surfaces should be inspected for finish.

4. Keyways should be inspected for placement.

Inspection of Spur Gears

1. Engine spur gears should be inspected while running on their own centers with two-thousandths back lash. This includes only spur gears.

2. Engine bevel should have six-thousandths back lash and are inspected on their own centers.

Inspection of Ball Bearings

All ball bearings, both radial and thrust, must rotate freely and show no perceptible shake.

Inspection of Engine

The following questions should receive the inspector's approval before he passes the engine for Government use:

Is engine fastened down properly when assembled in machine?
Are all connections made in the most approved manner?
Is carbureter adjusted properly?
Is oil pump working O. K. and is oil pressure good?
Are valves timed right and do valve stems have proper clearance?
Do valve stems have safety pin to prevent valve dropping in cylinder in case valve spring washer pin breaks?
Does engine have good compression?
Is camshaft in proper alignment so that valves on all cylinders open at their proper relative time? [1]
Is there any suspicious noise to be heard at any engine speed?
Are any of the valve springs weak?
Do rocker-arms hit valve stems squarely?
Are push-rods bent, or do they bind in any way?
Is propeller tight on crankshaft or jackshaft?
Are there any leaks in gas manifold, water manifolds, exhaust manifolds, oil pipes, or air line?
Does engine function properly at low speeds as well as high and with quickly opened throttle?
Has engine any bad "rough" point?

Inspection of Cable Wire, Turnbuckles, and Fittings

Cable

Are there any kinks in the cable?
Are loops properly made?
Are thimbles used in eyes?
Are ends wrapped properly (wrap must be at least 15 times diameter)?
No splicing of cable is permitted.
Has acid struck cable during soldering?
Are any of the strands broken?
Are wrapped ends stream-lined and show the result of skilled workmanship?

Roebling Hard Wire

Are there any file cuts or flaws to weaken it?
Is loop well made?
Is ferrule put on correctly?
Are there any sharp bends or kinks?
Are wires too loose or tight in machine?

[1] This should be checked carefully before cylinders are put on case and should be kept within close limits.

Fittings

Is workmanship good?
Is material good?
Are holes drilled correctly to develop proper strength?
Are there any deep file cuts or flaws to weaken it?
Is rivet or pin fastening wire put in properly?
Are thimbles of large enough diameter?

Turnbuckles

Any file cuts, tool marks, or flaws in shanks or barrel?
Are there too many threads exposed?
Is turnbuckle of right strength and size to develop full strength of wire?
Are shanks bent?
Are threads on shank or in barrel well made?
Is barrel cracked?
Is turnbuckle properly wired (see sketch under "Approved Method of Wiring Turnbuckles")?

Inspection of Linen

All linen used in airplane construction should be up to the following specifications:

Free from all knots or kinks.
Without sizing or filling.
As near white as possible.
Weight, between 3.5 and 4.5 ounces per square yard.
Strength per inch should comply with Signal Corps specifications.

Inspection of Propellers

Army inspectors should inspect all wood to be used in propellers for Government use. This wood should be well seasoned; free from knots, sap pockets, dry rot, and should be straight in grain.

Laminations should extend the entire length of the propeller of the two-bladed type and no splices should be allowed in laminations in the hub. On three-bladed type, the splices should be made so as to get greatest glue surface and greatest cross-section of wood.

Metal tipping should be inspected to see that the metal lies close to wood, that nails or rivets have not split the blade, and that solder is placed smoothly and properly.

Propeller hubs should be pressed into propellers on an arbor press, and great care should be taken that the wood is not injured in the process but that a tight fit is secured. Hub bolts should fit hub flanges with very small clearance but without filling, and should be a light drive fit through wood. The taper and keyway or splines should be carefully inspected and no nickel plating should be allowed in these surfaces. Hub bolts should be wired in an approved manner.

Before shipping from factory, all propellers should be checked for balance (standing) on true knife edges, for checks in wood, for cracks in glue joints, and for alignment of blades. This final inspection should be made immediately before shipping.

Propellers should be checked for pitch as per sketches or in some other approved manner.

The maximum allowable variation in checking blades of the same propellers is as follows:

	Maximum variation, in inches
For 8 feet diameter	0.24
For 8 feet 6 inches diameter	0.25
For 9 feet diameter	0.27
For 9 feet 3 inches diameter	0.28
For 9 feet 6 inches diameter	0.29
Alignment (to be measured at a point about 2 inches from tip):	
For 8 feet diameter	0.125
For 8 feet 6 inches diameter	0.166
For 9 feet diameter	0.200
For 9 feet 3 inches diameter	0.225
For 9 feet 6 inches diameter	0.250
Pitch (taken at points 62½ per cent., 75 per cent., and 87½ per cent. from hub):	
For 5 feet 5 inches pitch	1.00
For 5 feet 6 inches pitch	1.02
For 5 feet 11 inches pitch	1.10

Inspection of Radiators

Radiators should receive the following test:

Each radiator is to be submerged in water and tested with an air pressure of 6 pounds, and when passed must be free from all leaks. In inspecting radiators, care should be taken that provision is made to install in such a way that the radiators will not be injured by vibration.

Inspection of Wood

All wood should be inspected before varnish is applied. The following questions should receive the inspector's approval before he passes any wood for Government use:

Is grain satisfactory?

Are there any sap or worm holes?

Are there any knots that look as if they would weaken member?

Any brashiness?
Any holes drilled for bolts or screws that would weaken member?
Any splits or checks?
Are laminations glued properly?
Are there any plugged holes?
Any signs of dry rot?

Inspection of Metal Fittings

When fittings are copper-plated and japanned the inspection should take place after the copper-plating. The following questions should be approved by the inspector before being passed:

Have fittings been bent in assembly?
Does fitting show any defects that lessen its strength?
Are holes drilled properly?
Do fittings fit?

Inspection of Sheet Aluminum

Sheet aluminum should be inspected for defects such as cracks, bad dents, and under specifications in gage. Where openings occur in sheet aluminum the corners should be rounded, allowing a good-sized radius.

Correct Winding for Different-sized Cables

Windings must be even with a nice stream-line effect at end of winding. When solder is used, care should be taken that acid does not go beyond soldered portion of cable.

Dimensions *A* to be at least 15 times *D* or diameter of cable (see Fig. 117).

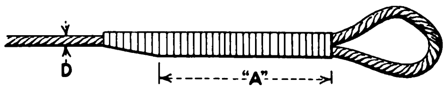


Fig. 117.—Correct cable winding.

Size of cable inch	Length of winding, inches	Breaking strength, pounds	Size of cable inch	Length of winding, inches	Breaking strength, pounds
1/32	1 1/2	185	5/32	2 3/8	3,200
1/16	1 1/2	500	3/16	3	15,500
3/32	1 1/2	1,100	7/32	3 3/8	6,100
7/64	1 3/4	1,600	1/4	3 7/8	8,000
1/8	2	2,100	5/16	4 3/4	12,500

[1] 5500 pounds for cable, but only 5100 pounds for loop

Only non-acid flux should be used in soldering.

Approved Method for Wiring Turnbuckle

Inspectors will examine all turnbuckles in every assembled machine to ascertain that these parts are locked in a manner complying with the best practice. When wire is used to lock the turnbuckle it should be of 20 gage hard copper wire and secured in an approved manner. Wiring as shown in Fig. 118 proved most satisfactory.

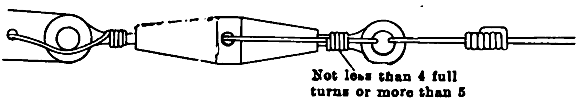


Fig. 118.

Notes on Turnbuckles and Connections

Standard test for turnbuckles: Rods are screwed into barrel full length of threads on rods, so that last thread is flush with end of barrel, unless otherwise stated.

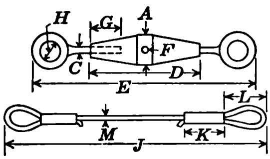
Turnbuckles held by pin connections.

Piston speed of testing machine 0.1 inch per minute.

Elongation is measured as per cent. of length of rod, when break occurs in rod, and per cent. of total length of barrel when break occurs in barrel.

Standard Dimensions and Letters for Turnbuckle Sketches

Inspectors submitting wire or cable test specimens to this office for test by the Bureau of Standards should follow the procedure as shown below, Fig. 119:



Dimensions											
Turnbuckle								Connection			
A	B	C	D	E	F	G	H	J	K	L	M

Fig. 119.

The specimen should be 30 inches long with the standard connections used in service by the manufacturer attached to both ends.

TESTING OF IGNITION SYSTEMS

A. BEFORE MOUNTING ON ENGINE

It is advisable to test the ignition system before it is mounted on the engine, as this may save considerable work later in tracing troubles.

I. MAGNETOS

Testing Figures.—1. Mount magneto on a stand. This should consist of a metal plate with means of fastening the magneto; the test stand must consist of non-magnetic metal, such as aluminum or brass, and be connected to a grounded water or gas pipe in order to avoid static discharges.

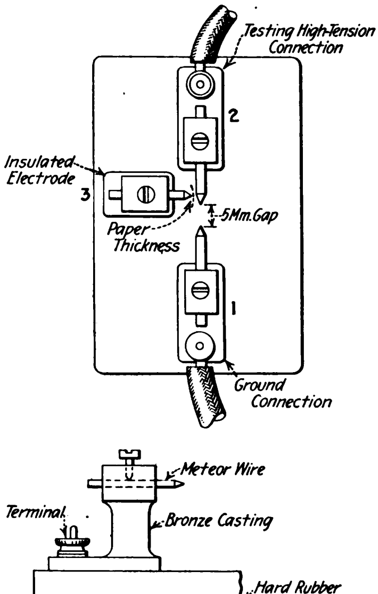


FIG. 120.—Testing magnetos.

2. Provide magneto with a pulley for driving; pulley with two or three steps of different radii and with a belt groove on each step for driving at different speeds is preferable.

3. Provide necessary amount of test spark gaps, one for each high-tension terminal on the magneto, see Fig. 120. Clean test spark gaps with

alcohol in order to remove all moisture and prevent surface leakage of high-tension current. Adjust test spark gaps, distance from (2) to (3) should be so as to allow a thin piece of paper to be slipped in between the points, without the paper being torn, but the paper should touch both points at the same time. Distance between (1) and (2) should be 5 millimeters; connect (2) to high-tension terminal on magneto and (1) to the grounded test stand.

4. Use standard high-tension cables for making connections; all contacts must be good and all connections tight.

Adjustments of Magneto.—5. If possible, remove cap on breaker box, so that operation of breaker points can be observed during test. Adjust the distance between the breaker points before the test; the distance should be as follows:

Dixie magnetos, 0.45 to 0.55 millimeter, or 0.018 to 0.022 inch.
Berling magnetos, 0.40 to 0.50 millimeter, or 0.016 to 0.020 inch.
Bosch magnetos, 0.35 to 0.45 millimeter, or 0.014 to 0.018 inch.

Breaker points must be clean, make contact over the whole surface, and line up properly; no pitting, burning, or oxidizing must have taken place.

Test.—6. Allow magneto to run for 10 minutes in order to be run in before starting the test; the speed of the magneto during the test should be 15 per cent. over the rated magneto speed. Rated magneto speed means the speed at which the magneto is running when the engine is running at its full rated speed. The magneto should be tested for 3 hours at above speed.

If it is found necessary to change magnetos after the engine has made the 6-hours' run, the new magneto should be given a 6-hours' run on the test bench at 15 per cent. over rated speed. After this, the magneto is mounted on the engine. The engine should then be tested for 1 hour on dynamometer to check up the power at full rated speed.

7. Observe closely the sparks; all sparks should be of the same size—*i.e.*, the corona or the flame on the sparks should be of the same size and be even, not show periodical increasing or decreasing. It is necessary to watch a spark closely for 2 to 3 minutes in order to detect any missing. No missing must appear at above speed.

8. Watch closely the performance of the breaker points. No arcing between the points must take place. Listen for excessive noise from the ball bearings; excessive noise indicates that the bearings are not properly adjusted, and this may cause breakdown in short time.

9. For the slow speed, run the magneto at approximately 50 r.p.m. and increase the speed slowly until the sparks appear absolutely regular without missing. This should be done with the magneto in full advance, as well as in full retard position. Note these speeds: It should not exceed 100 to 150

r.p.m. for full advance, and 200 to 275 for full retard position, as the starting of the engine otherwise will be too difficult. The variation of the magneto speed can be made by using a friction disc arrangement, or if an electrometer is used by changing the resistance in the field and in the armature.

Inspection of Magneto after Test.—10. After the test is finished the magneto should be inspected and the following points noted:

The breaker points must still be in good condition; no burning must have taken place.

Remove the distributor plate and see if carbons show any excessive wear. The wearing surface should show a high polish, and no carbon dust should be seen inside the distributor plate.

The segments inside the distributor plate must not show any burning of the edges, and the entire surface should show a good polish. Segments must not extend beyond the surface of the insulation composition.

Reassemble the magneto and it is then ready to be mounted on the engine.

II. Battery System

11. Mount the timer distributor similar to the magneto. This requires special fixtures, which do not necessarily have to be of non-magnetic material. Provide a pulley for driving the timer distributor in a similar way as for magneto under No. 2.

12. Make proper connections between the timer distributor, high-tension coil, and storage battery, as indicated on manufacturer's diagram, and make high-tension connection to test spark gaps as for magneto under No. 3. Do not make final connection between the high-tension coil and the storage battery until immediately after the timer distributor is started to run, as the excessive current which passes through the coil when the timer is standing still will injure the coil if it is allowed to flow for any longer period. Connect an amperemeter with scale reading 0–25 amperes in between the storage battery and the coil, and report the current consumption when the timer distributor is running at rated speed.

13. Use a storage battery of not less than 50 ampere-hours, and ascertain before test that the battery is 75 per cent. charged—*i.e.*, reading with hydrometer should show not less than 1200 "points;" connection to storage battery must be clean.

14. Make all adjustments as described for magneto under No. 3, No. 4, and No. 5, and make test as described for magneto under No. 6, No. 7, and No. 8.

15. Inspect the timer distributor as under No. 9.

B. After Mounting on Engine

I. Magnetos

Setting.—16. Check the point of firing. This depends on the type of engine, compression, and ignition system used; battery ignition calls for a larger degree of advance than does magnetic ignition; the proper point of setting is decided by the manufacturer of the engine. The point of firing can be measured on the piston stroke in inches, but it is preferable to measure it in degrees on a graduated dial, if such can be placed on the crankshaft or on the propeller hub.

17. If two independent ignition systems are used, the difference in firing point between these should not exceed 2 or 3 degrees. This should be checked up in the same way as above.

Wiring Cables.—18. See that all terminals are in good condition, give good contact, and that all terminals are tight and secured. Check up all wiring. High-tension cables must be held in tubing of insulation material or strung free in the air, held at intervals by supports of fiber or bakelite, but should not be inclosed in metal tubing. High-tension cables should not come in contact with any grounded metal, as this in time may cause breakdown. High-tension cables should be held in such a way that no movement of the cables can take place, as this may result in chafing of the cable insulation.

Spark Plugs.—19. Check up the gaps in the spark plugs; the size of the gaps depends on the type of motor, compression, speed of motor, and ignition system used. The gaps should be approximately 0.016 to 0.025 inch where magnetos are used and 0.025 to 0.032 inch where battery systems are used. It is important that all gaps in same motor be of the same size and no leaks must be visible around the spark plugs.

20. Note especially the performance of the different makes of plugs in regard to cracked porcelain due to heat or from mechanical reasons; note short-circuits due to wrong design of porcelain; note electrical punctured plugs where no mechanical crack is visible; note trouble with plugs where no apparent reason can be found. This may be due to leaky porcelain. Note if design of motor does not allow for proper cooling of the plugs or if the porcelain is flame-swept. It is important that these points be carefully watched and that all information, with samples, be correctly and quickly submitted.

Performance.—21. Check up opening of breaker points as under No. 5, check up that no damage is done to the magneto, such as denting the cap on the breaker box, cracked magnets, loose or missing screws, loose cams in the breaker box. Inspect the breaker points while the motor is running at the rated speed. No arcing should take place with the magneto in full advance position.

22. If the location of the magneto is such that oil from the engine settles on any part of the magneto, it will be necessary to provide proper leather covers for the magnetos. This is also necessary if the magneto on a seaplane is exposed to salt-water spray, even if the magneto is of the so-called waterproof type.

Test the magnetos and spark plugs with the engine running by short-circuiting one magneto at a time. If any difference in the running of the engine can be noticed, then the spark plugs or the magneto which is not short-circuited is at fault. Inspect all the spark plugs and exchange those which are defective, short-circuit again one magneto; if the trouble still exists, it is due to the magneto and a new magneto should be mounted on the engine.

23. If one engine shows more vibrations than others of the same type, the reason may be due to uneven firing of the magneto—*i.e.*, the two breaks are not exactly 180 degrees apart; replace the magneto with another which has proven satisfactory; in case the vibrations decrease, the magneto is at fault and should be returned to the manufacturer.

II. Battery Systems

24. Check up the point of firing in the same way for magnetos under No. 16 and No. 17.

25. Check up wiring and cables as under No. 18; all low-tension cables should be armored with flexible tubing and the terminals of such design that the nuts cannot loosen up due to vibrations from the engine.

26. Check up the gaps in the spark plugs as under No. 19, and report on performance of different makes of plugs as under No. 20.

27. Check up all points as described for magnetos under Nos. 21, 22, and 23.

C. Care of Ignition Systems

I. Magnetos

Cleaning and Oiling.—28. Clean the inside of the distributor plate with alcohol or gasoline, and wipe dry. This should as a rule be sufficient, but in special cases a little powdered soapstone may be used as a lubricant, but it should be avoided if possible. The breaker points may, if dirty, be cleaned with a little alcohol or gasoline. Care should be taken when using these combustible liquids that all moisture is wiped off again or allowed to evaporate before starting the magneto, as a spark may cause explosion and fire. The breaker points can be filed, even if they are pitted or burned, by means of a watchmaker's file; sandpaper or emery cloth should not be used, as this is liable to leave particles of glass or emery between the points, thus preventing good contact.

29. Use only "3-in-1" oil for lubrication of the magneto, and apply only one drop at a time, *as more damage is done by overlubrication than by underlubrication.* No oil should under any circumstances be applied to the breaker points, as provision for lubrication is made automatically from ball bearings. Lubricate the cams in the breaker box by using a small amount of vaseline, wiping it off so that only a very thin coat is left.

30. Armature end play should not exceed 0.01 inch. In case it is more the magneto should be returned to the manufacturer. No attempt to remove the magnets or the armature for inspection should be made, as it requires special fixtures to reassemble these parts again. Important repairs should be made by the manufacturer of the magneto or by the testing laboratory in Hampton, Va.

Clean porcelain spark plugs by scraping the carbon and oil off the porcelain and washing with gasoline or kerosene. Clean around mica spark plugs by scraping the outside layer of mica off with a penknife; scrape in a direction parallel with the center electrode, as this will not tend to loosen the winding of the mica. A mica plug cleaned in this way is as good as new. Do not use emery cloth, as particles of emery are liable to stick between the layers of mica.

II. Battery Systems

Cleaning and Oiling.—31. The same points as given under 28, 29, and 30 for magnetos apply to battery systems.

Care of Storage Battery.—32. Batteries must be installed so that they are easily accessible. Battery compartment must be ventilated and drained; battery should have free-air space on all sides and should rest on cleats; holding devices should grip case or case handles.

33. Keep battery and interior of battery compartment wiped clean and dry; do not permit an open flame near the battery; keep metal pieces and tools away from battery and keep terminals coated with vaseline.

If the solution has spilled out, wipe off with waste, wet with ammonia water.

34. Add pure distilled water to battery whenever the solution is below the mark; the solution should always cover the plates. Screw the plugs down tight after filling so that the solution cannot leak out.

35. Measure from time to time the gravity of the battery solution by means of a hydrometer. Reading above 1200 indicates that the battery is over half charged, reading below 1200 indicates that the battery is less than half charged. A run-down battery should be given a full charge at once, and charging should be continued until the solution shows a reading of 1300 points, even if it requires twice as long time as for a normal charge. Acid should never be added to the solution in order to bring the gravity up to

full value. If the battery loses its charge when standing idle, or if one cell gives a considerably lower reading than the others, there is some internal trouble, and the battery must be returned to the manufacturer for repairs.

36. When charging the battery, use direct current of a voltage 50 per cent. higher than the battery voltage, and connect the positive terminal of the battery to the positive charging wire. A battery which has been standing idle for more than a month should be given a thorough charge before being used again. A battery should never be left standing idle for more than 6 months, but should, if possible, be given a charge once a month.

Spark-plug Trouble

Most of the spark-plug trouble experienced in aviation engines seems to be caused by leaky plugs; not leaky to electricity, but leaky to hot gases.

This is due to several portions of the construction: First, the cement used around the center electrode; and second, the washer which is supposed to be gas-tight, but which is not.

Pressure Test.—A pressure test of 80 pounds per square inch shows many leaky spark plugs. The gases blow by, overheating the plug, crack the porcelain, and otherwise cause failure.

This difficulty can be overcome to a great extent by soaking all copper asbestos gaskets inside the plugs, and between the plugs and the cylinder head, in a solution of 50 per cent. boiled linseed oil and 50 per cent. kerosene. This mixture will soak into the asbestos and bake hard when the engine warms up, thus forming a compression tight joint. The gaskets can be prepared several months before being used. It is also recommended to use copper asbestos gaskets, which has the opening on the face of the gasket instead of on the periphery of the circle; the opening will then be closed by pressure which will make it gas-tight.

Suggestions and Sketches

When inspectors have suggestions to be sent to this office for approval, care should be taken that the wording is made clear and, if possible, a sketch should accompany the suggestion. It is desired to encourage inspectors in making suggestions for the improvement of either the materials sold the Government or the system of inspection. They should not, however, spend time making suggestions and sketches at the expense of the regular inspection work.

Glue

The following remarks refer to glue made only from animal hides, sinews, etc., and from fish.

When glue is heated in solution its adhesive power deteriorates, and so rapid is this deterioration that glue may lose one-third to one-half its adhesive power in the course of a single working day of 8 to 10 hours. In shops where this fact is appreciated, great care is taken to keep the time of heating down to the lowest limit. Sufficient glue for the day's work should be melted, cooled and the jelly served out in small portions to the workmen so that it may not be kept hot too long. Great care is also exercised to clean out the glue pots every night before quitting work. Much of the trouble experienced with supposedly bad glue is due to the spoiling of good glue by long heating. The best practice seems to be not to let the temperature go above 140° to 150°.

In joining wood, the choice of the glue will be dictated by the kind of woods and its condition as well as the nature of the joint and the kind of strain it is expected to bear, as to whether it is subjected to gradual or sudden strains, to pull of shearing stress, and the condition of heat and moisture to which it is to be exposed.

Test Specimens of Glue

All airplane companies should submit samples of their glueing for test. The samples can be made up in either of two ways:

1. According to the blue print of the shear test specimen issued by the Aviation Section of the Signal Corps see Fig. 121.

2. In the form of three planks glued together throughout their full length. Outside planks to be 5½ by ¾ inch by 4 feet; middle plank, 5½ by 1 inch by 4 feet.

The following information should be furnished with the glued specimens:

1. Kind of glue.
2. Manufacturer of glue.
3. Price per pound.
4. Length of time glue is made up before being used.
5. Amount of water mixed with the glue. Pounds of water to one pound of glue.
6. Temperature of glue as applied.
7. Maximum melting temperature of the glue.
8. Thickness of the glue film and method of application.
9. Pressure applied to the surfaces after spreading the glue.
10. Time allowed for the glue to set.

The samples sent in for test should include all varieties of wood used by the company sending in the specimens.

The samples should be accompanied by at least ½ pound of the glue for ash, water absorption and viscosity tests.

A–B are glued surfaces under test, 10 square inches.
A–A section in compression, 2½ square inches.
This is the ratio that should be used (see Fig. 121).

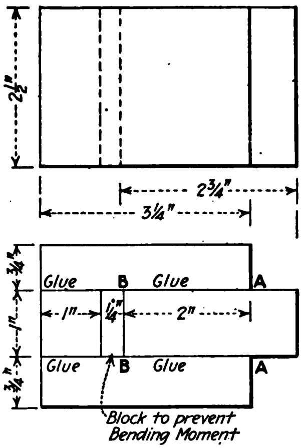


Fig. 121.—Glue test blocks.

Stamping Materials with Government Stamp

When material is to be stamped by an inspector as acceptable for Government use, the inspection stamp should be placed so as to be easily seen after the machine is assembled.

Inspection and stamping of parts will be made by Army inspectors as follows:

Wing beams will be inspected before being assembled in the wing and stamped on the inside near the hinge end.

The wings will be inspected just before covering and will be stamped on the hinge.

Rudders, stabilizers, elevators, and fins will have the metal work inspected before painting and enameling. These assemblies also will be inspected just before covering and stamped on hinges.

Longerons will be inspected before assembly and stamped near splice.

Bodies will be inspected before being covered and stamped on the inside of the upper longeron, at the pilot's seat.

All radiators will be inspected by Army inspectors and tests on all radiators shall be viewed by inspectors.

Propellers will be inspected before varnish is applied, and stamp mark will be made on outer face of hub outside of propeller hub flange.

Engine parts should be stamped where easily seen after engine is assembled, or where most convenient where this is not possible.

Samples for Test of Analysis

Inspectors submitting samples for chemical analysis by the Bureau of Standards should send at least 3 ounces. When less than the desired quantity is available, several of the determinations may be made on a single sample, and in certain cases a smaller quantity may be used with but slight loss in accuracy; but in case only a limited quantity can be obtained, special tests must be developed so that the maximum information will be furnished from the minimum quantity of material.

Inspectors submitting linen samples for test by the Bureau of Standards should prepare test pieces as follows: Pieces should be cut 1 yard in length and the full width of the fabric.

When connections are sent in for test it is important that the diameter of the pin used with connections be specified.

At least three of any lot of turnbuckles should be tested for breaking strength and reduction of area. The turnbuckles used for this test should be those which are, in the opinion of the inspector, the poorest of the lot.

Structural parts sent in for test should be accompanied by blue prints or sketches showing the location of the part and the load it is designed to carry.

Fractured parts sent in for examination or microphotographic analysis should be carefully handled and protected before and during transit to preserve the original appearance of the fracture.

Information of Materials Used

A record of the materials used in the construction of machines and engines should be kept by the inspector at a factory and a copy of same forwarded to this office.

The record for iron and steel fittings or parts should give the following information. Tests of the material should be made in the presence of the inspector.

Yield point:
- Tensile strength.
- Ductility, 2 inches or 8 inches.
- Reduction of area.
- Kind of fracture.
- Appearance of fracture.

Chemical analysis (certified to by the chemist performing the analysis).

Wing coverings:
- Weight, before and after doping.
- Tensile strength.
- Thread count.

Dopes:
- Number of coats.
- Number of coats varnish.

Wood:
- Modulus of elasticity.
- Modulus of rupture.
- Compressive strength.

Wire:
- Breaking strength.
- Number of 90-degree bends before breaking.

Gears and small parts of motors:
- Scleroscope hardness.
- Brinnell hardness if possible.
- Chemical analysis.
- Heat treatment.

Crank case and water jacket.

Same as for other metals. Test to be made on test coupon with the casting.

Tools for Standard Equipment of Inspectors

1 set of calipers, improved extension, 9-inch, with case.
1 set of tools, Starrett, in case, consisting of—
- 1 tape measure.
- 1 calipers, 5-inch.
- 1 gage, depth.
- 1 gage, tapper and thickness.
- 1 bevel and protector, universal.
- 1 rule, 9-inch.

1 micrometer, 1-inch, in case.
1 set dies, steel, 5/8, 1/2, 1/8.
1 magnifying glass.
1 wrench, crescent, 4-inch.
1 thermometer, glue-testing.
1 gage, micrometer test.
1 set steel letter alphabet and figures.

In requesting that a set be forwarded to a certain inspector the foregoing is to be considered a set. In case of exceptions, the special memorandum from this office will so specify.

SECTION XVII

SPECIFICATION FOR U. S. A. MILITARY TRAINING (ADVANCED) AIRPLANES

I. Preliminary

This specification describes the design, construction, equipment, and requirements of a military airplane adapted to advanced school instruction in land flying. The motor to be supplied by the Government.

II. General Requirements

The following characteristics shall be proven to the satisfaction of the inspectors appointed by the Government for that purpose.

1. This airplane shall be a two-place tractor biplane with one fuselage, and to be equipped with one motor. It shall be suitably constructed for carrying a pilot and one passenger, and shall be designed for carrying a useful load comprising the following:

(*a*) Pilot and passenger, 330 pounds.

(*b*) Supply of gasoline, oil, and water necessary for a flight of 4 hours' duration with motor turning continuously the number of revolutions per minute required for its rated horsepower. The rate of fuel consumption may, at the discretion of the inspectors, be based upon a flight of 2 hours' duration with motor turning continuously the number of revolutions required for its rated horsepower. There need be only one such flight for the entire group of machines.

Unless otherwise specified in the order, the useful load carried on all performance tests shall be equivalent to the above.

2. The airplane shall be designed for a Curtiss, eight-cylinder, model OX–
... combustion engine, rated at 90 horsepower at 1400 r.p.m., or for
... made motor, approved by this office, of actual horsepower
... and 110.

... ntal low speed shall not exceed 43 miles an hour.

... horizontal high speed shall not be less than 75 miles

... n of the inspectors, at least one machine of the group

delivered, to be chosen at random by the inspectors, to attain, in less than 75 minutes, an altitude of not less than 10,000 feet above sea level, starting with the above useful load.

6. The climb shall not be less than 3000 feet in 10 minutes under conditions set forth in Paragraph IV.

7. *The air-worthiness and general flying qualities of the airplane to be satisfactory.* These include celerity of response to control, the proper degree of symmetric and asymmetric stability (static and dynamic), steadiness in disturbed air, etc., under various flying conditions. ***The primary consideration in design should be that of producing a machine suitable for advanced instruction of novices.***

In order to determine the above attributes, an Army pilot may, at the discretion of the inspectors, fly any or all machines, executing sharp figures of "8," dives, stalls of various kinds, side-slips, sudden stopping of motor while climbing steeply, releasing of controls for a period of time after the machine has been steadied in horizontal flight, and such other maneuvers as he may deem necessary to determine the general suitability of the machine.

8. *Maneuvering on the Ground.*—Maneuvering ability on the ground shall be satisfactory. The machine shall be capable of making reasonably sharp turns to right and left, or of being driven along a straight course in any direction with respect to a moderate wind.

9. Both the Curtiss (shoulder or chest yoke) and Deperdussin types of control shall be furnished ready for installation in both cockpits. The control shall be dual for both types. By this is meant that two combinations are possible, *i.e.*, dual Deperdussin, or dual Curtiss. Mechanical ease of operation is essential. The control to be installed will be indicated in the order.

III. Construction, Design, Etc.

1. Factors of safety will be required as follows:

(*a*) Main plane structure. Conditions assumed:

(1) Load as above.

(2) Angle of incidence of mean chord of main planes; that of maximum lift coefficient.

(3) Air speed: That normally corresponding to the above load and angle of incidence for the net effective surface area.

Factor of safety is to be not less than seven and one-half (7.5).

(*b*) Body and tail structure. Conditions assumed.

(1) Air speed, 100 miles an hour.

(2) Angle of incidence of fixed horizontal tail surface, minus 6 degrees; elevator surface, minus 20 degrees.

Factor of safety is to be not less than 2.5.

(*c*) The strength of construction of all parts (extreme flying and landing conditions being considered) to be satisfactory.

2. All details of construction shall be satisfactory, and conform to the best proven and approved practice.

3. The following drawings *in triplicate*, shall be furnished:

(*a*) Complete sets of factory working drawings of the complete airplane.

(*b*) Accurate drawings to scale of a complete machine showing: (1) Plan. (2) Side elevation. (3) Front elevation; on which shall be indicated all dimensions, areas, and relative angles.

4. *Price Lists.*—A complete list of all component airplane parts with proper designating numbers and prices shall be furnished. In addition to the above, the data indicated on the standard forms inclosed herewith shall, as far as practicable, be included.

5. *Instruments and Accessories.*—The following instruments and accessories shall be provided. Their location, design, and arrangement shall be such as to cause them to function with satisfactory precision and reliability under various flying conditions.

(*a*) Aneroid barometer, graduated in feet, registering from sea level to 12,000 feet; to be installed in rear cockpit.

(*b*) Clock in rear cockpit. (Chelsea preferred.)

(*c*) Case or box for tool kit, to be installed immediately in rear of the pilot and readily accessible.

(*d*) Shaft revolution speed indicator, to be installed in rear cockpit. (Warner preferred).

(*e*) Gasoline-supply gage in rear cockpit.

(*f*) Oil sight-gage in rear cockpit.

(*g*) Radiator water thermometer, visible from rear seat.

(*h*) Throttle controls (both hand and foot) to be installed in both cockpits.

(*i*) Ground wire switches to be installed in both cockpits.

(*j*) Spark advance controls to be installed in both cockpits.

(*k*) Pressure indicators for gas system installed in both cockpits.

(*l*) Method of cutting off gasoline supply between carbureter and gravity tank from both seats.

(*m*) Safety belts on both seats.

(*n*) One Pyrene fire extinguisher mounted on convenient bracket, readily accessible to both men.

6. *Landing Gear.*—The landing gear shall be of very sturdy construction throughout, of the two-wheel type. To be such as to render the machine capable of being landed in or flown out of a field in which the ground is fairly soft or fairly rough; and to undergo, without injury, a moderately rough handling. The wheels shall have 26 by 4-inch tires and 6 by 1½-inch hubs, and have tangential spokes.

7. *Fuselage.*—The fuselage shall be of one part, not the jointed tail type. All turnbuckles in the fuselage wiring shall be so located as to be readily accessible. In the side wiring they should be near the upper longerons.

The wing spar fittings on the fuselage to which the lower planes are attached shall be tied together across through the fuselage by steel tubing.

The interior of the fuselage shall be so constructed as to permit thorough inspection of all wiring, control leads, etc. As far as practicable all leads shall be direct.

8. *Tail Skid and Vertical Rudder.*—The design and mounting of the tail skid and vertical rudder shall be such as to prevent injury to the vertical rudder in case of failure of the tail skid.

9. *Turnbuckles.*—The number of different sizes used shall be reduced to a minimum. All pulleys, pins, bolts, turnbuckles, etc., shall be drilled for safetying. Safety wire shall be of No. 18 gage copper wire.

10. *Field of Vision.*—The fields of vision for pilot and observers shall be satisfactory. These will be indicated on the blue prints submitted with the machines.

11. *Arrangement of Seats.*—The seats shall be arranged in tandem, one seat being directly in the rear of the other.

12. *Cockpits.*—The edges of both cockpit holes shall be well padded, and a suitable detachable transparent wind shield provided for both pilot and observer. The seating and cockpit arrangement for pilot and observer shall be comfortable, secure, and convenient, and such as to permit, as much as is possible at the same time, easy observation and protection against draft. The arrangement of the cockpit shall be such as to permit pilot and observer to get clear of the machine quickly in the event of an accident, without undue danger of becoming entangled in wires, etc. Safety belts of webbing, with approved quick-release devices, shall be securely anchored at convenient points in both cockpits.

13. *Motor Installation.*—The ease and convenience of removing motor from and installing motor in airplane with a minimum disturbance of connections, controls, structure, etc., shall be satisfactory. The housing around the power plant shall be readily detachable, and, in addition, have means to permit convenient access to all parts of the motor which may require adjustment or inspection.

The vibration at various motor speeds and under various conditions must not be excessive.

14. *Radiator.*—The radiator shall be of approved design and so constructed as to be proof against the action of vibration.

15. *Gasoline Tanks.*—Gravity feed throughout is preferred. If gravity feed is not used throughout, a positive and reliable system of pumping gasoline from the reserve tanks to the gravity tank shall be provided.

A gravity-feed tank capable of holding a supply sufficient for at least 40 minutes running at full rated horsepower of the motor to be securely installed in such a place that the feed shall be positive, reliable, and sufficient in all flight attitudes up to 30 degrees inclination, either climbing or gliding. The remaining tanks shall be placed near the center of gravity of the machine. All fuel tanks shall permit of being drained from the bottom. The gasoline tanks, oil and water reserves shall be of sufficient capacity to permit a flight of at least 4 hours' duration in hot weather with motor turning at the number of revolutions per minute required by its full rated power.

Fuel tanks which may in service be subjected to internal pressure shall be of sufficient strength to withstand an internal pressure of at least 6 pounds per square inch. Where necessary, fuel tanks shall be divided by the proper number of swash-plate bulkheads.

16. *Service Pipes and Connections.*—Gasoline, oil, and water service pipes and connections shall be proof against vibration. A positive means of cutting off the gasoline supply at the service tank shall be readily accessible from both seats. All gasoline tubing to be satisfactory as to flexibility, durability, impenetrability, and to have been tested for leaks after vibration.

Gasoline leads to reserve tanks, the control leads, and other methods of adjustment shall be provided with suitable safe and readily accessible couplings.

17. *To Stop Motor.*—At least one reliable method of stopping the motor shall be provided, capable of operation from both seats.

18. *Carburetion and Oil Feed with Motor Tilted.*—The oil-supply system, carburetion, etc., shall be such as to permit the motor running satisfactorily at angles of inclination (lateral or longitudinal) up to 25 degrees (either way) to the horizon.

19. *Backfire Protection.*—Positive and reliable means should be provided to prevent backfire spreading beyond the carbureter.

20. *Wings—Overhang.*—The upper plane shall extend beyond the lower plane laterally by an amount approximately equal to the chord.

Trailing Edge Flaps.—The lateral control shall be by means of trailing edge flaps on the upper plane only.

The wing covering to be of the best grade of raw linen, of weight not less than 3.75 ounces per square yard. The method of covering the wing shall be the R. A. F. method of sewing and such as to render the cloth of the proper tautness, smoothness, and security. Surfaces shall be dyed and varnished in such a way as to afford satisfactory protection against the action of rain and weather.

The color scheme shall be as nearly white as practicable, using standard dopes and varnishes.

Stay Bracing.—Stranded steel cable shall be used for all tension members which are readily accessible for adjustment and for all control leads. Structural tension members shall be of hard cable and control leads shall be of flexible cable. Cable terminals shall be wrapped and soldered. Spiral wire clips, without solder shall be used for terminals of hard single-strand wire. No spliced terminals in hard cable will be accepted.

All cables which are members of the wing structure and normally under tensile load in flight shall be in duplicate and made independent between fittings.

Satisfactory provisions shall be made, as far as is practicable, for convenient and thorough inspection of control cables and pulleys and vital structural members.

In the internal wing bracing the compression members carrying the drag of the wings shall be separate wooden struts and *not* wing ribs.

Rib webs shall be reinforced between lightening holes to strengthen them in longitudinal shear.

21. *Tipping Propellers.*—The material and method of tipping propellers shall be such as to insure protection against the action of sand, as well as to render the tips secure in place.

22. *Assembly, Disassembly, and Packing.*—The provisions for rapid assembling and disassembling, and for packing in crates of convenient size and shape for transportation, shall be satisfactory. Detachable bolts, fittings, and other parts shall be as few in number and as simple as is consistent with other requirements.

IV. Tests

Any or all of the following rules governing the method of conducting performance tests may be enforced at the discretion of the inspectors:

1. Any or all machines must pass any or all tests to demonstrate guaranteed performances and to demonstrate that all provisions of this specification have been complied with.
2. All tests shall be started at approximately sea level.
3. For all tests the power plant and airplane shall be identical in every detail with the arrangement it is proposed to use in practical service.
4. The same type propeller, the factor of safety of which is satisfactory, shall be used for all tests.
5. The motor shall not be driven during any performance tests at a speed greater than 1400 r.p.m. (does not apply to other than Curtiss OX–2).
6. The gasoline used shall be standard automobile gasoline testing not higher than 65°Bé.
7. The number of officially observed attempts for each performance shall be decided upon by the inspectors at the time of the tests.

8. Before arriving at the starting point for each of the speed tests, machines must be flown at a height of not more than 25 feet for a distance of not less than 900 feet. The original altitude must be maintained over the specified course from start to finish.

9. The location and length of the course for the speed tests shall be decided by the Government.

10. The period of time for the climb shall start at the instant the wheels leave the ground for flight.

11. Climbing and speed tests shall be made by a pilot in the employ of the company.

12. Stop watches, barographs, and other instruments necessary for measuring the speeds and the rate of climb shall be provided by the Government. The fuel and oil shall be supplied by the Government.

13. The inspectors may, at their discretion, prohibit unreasonable delays in performance tests, caused by adjustments in power plants or airplanes which should, in the opinion of the inspectors, have been made before the date of delivery as guaranteed in the contract.

14. There shall be an inspection of the machines immediately after any test, to show that all parts and connections of the power plant and of the airplane are in good condition.

V. Inspection of Factory During Construction

One or more designated representatives of the Government will be present at the factory during the construction of the airplanes ordered. These representatives will be present in the capacity of inspectors, and will observe the following points, and such others as they may deem advisable:

That the constructors provide the proper strength of construction and the proper quality of material and grade of workmanship for each machine; that they make satisfactory provisions against deterioration of structural and other parts due to wear, vibration, and the action of salt water and moist air, varying climatic conditions, etc.

To determine that the constructors have an effective system of expert inspection to insure the above qualities.

That all details of construction conform to the best proved and approved practice.

To require such tests of material or of assembled or component parts as is deemed necessary, and observe such tests.

To reject any unsatisfactory part at any time during the construction of any machine at the factory.

To require supplementary tests as desired, of materials and parts when deemed advisable.

To see that steel used in construction is of such a grade as to have a high resistance to crystallization due to vibration.

The use of such other materials as have not been proved by test or experience to be non-subject to crystallization due to vibration will be discouraged.

To see that provisions for the protection of metal parts, and adjoining wooden parts, against the corroding action of salt water and moist air are satisfactory.

If laminated wood parts are used, to see that provisons for protecting them against the action of salt water, vibration, etc., are satisfactory. Particular care shall have been exercised to prevent access of moisture at faying surfaces, to end grain butts, scarfs, and joints, and such protection must be applied before the final assembly of parts.

To see that the threads of all bolts and nuts used in the construction conform to the S. A. E. standard.

Interchangeability of parts, assembled and component, fittings, etc., will be considered desirable, but this attribute should not interfere with others.

At the request of one of the inspectors, the contractor shall furnish the inspector the following:

Data which will show the capacity of the factory and affiliated factories, and the standing and the responsibility of the firm.

Drawings pertaining to the construction of the airplanes being supplied.

It will be considered desirable to have authenticated data from wind tunnel tests on an exact model of one of these machines, made to a suitable scale, as follows: Pitching moments (force vectors being plotted), at angles of incidence (mean chord, main planes) from minus 9 degrees to plus 24 degrees, observations taken every 3 degrees, and in addition at the following angles: Minus 2 degrees, minus 1 degree, plus 1 degree, and plus 2 degrees. The model shall have movable elevator surfaces cut off for the tests.

Data showing the elastic limit, hardness, and other important physical characteristics from authenticated records of tests on the exact steels (exact including final heat treatment, if any) used in the construction of the various parts.

Reliable historical information regarding the origin and time and method of seasoning of the material for wooden parts.

Records of tests of glue, cement, shellac, varnish, or dope, when required; such tests should comprise alternately soaking in salt water and drying, etc.

In the event of a decided disagreement between inspector and manufacturer on a point which involves considerable expense on the part of the manufacturer in order to effect the change required by the inspectors' suggestion, the matter shall be referred to the officer in charge of the Aviation Section for decision.

Inspectors and their assistants shall be given free access at all times during the manufacturing of airplanes or parts thereof being constructed in accordance with this specification, to any and all parts of the factory in which a part of the airplane is handled.

Acceptance of an order under this specification shall signify that the contractor agrees to all of the provisions of this specification and that the true intent and purpose of these provisions will be adhered to.

GEORGE O. SQUIER,

Lieutenant Colonel, Signal Corps, United States Army,
In Charge of the Aviation Section, Signal Corps.

OFFICE OF THE CHIEF SIGNAL OFFICER.

SECTION XVIII

DETAILS OF TRAINING PLANES

The machine illustrated in Fig. 122 is a biplane that has been designed particularly for training-school purposes. This means that it must be of sturdy construction to withstand the constant

FIG. 122.—Front of training machine.

hard usage given in a military preliminary training school, where it is handled almost exclusively by untrained men. It will be noticed that this machine has a three-wheeled landing gear, the small front wheel being for the purpose of preventing the machine from nosing into the ground, even if the landing is not exactly as it should be. There is of course the usual tail landing skid in addition to the three wheels in front.

In common with all modern training machines, there are provisions for two persons, each in a separate cockpit, one in front of the other, and each provided with a separate control so that the student can gradually become accustomed to handling the machine when it is in the air.

THE MAIN DIMENSIONS

The span of the upper wing is 43 feet 10 inches, and of the lower wing 32 feet, making an overhang of nearly 6 feet on each end. The chord, or width of the wing, is 6 feet, and the gap, or distance between the wings, 71 inches. This follows common practice of making the distance between the wings about the same as the chord. Increasing this distance adds to the length of the wing struts and requires that they be of heavier section, owing to the increased length. Lessening the distance between wings decreases their efficiency as supporting surfaces.

The stagger, or the distance which the upper wing projects in advance of the lower, forms an angle of 4¼ degrees with the front edge of the lower frame. This amount is often given in inches, and in this case would be about 5¼ inches. The overall length of the machine is 26 feet 7 inches, and the height 10 feet 10 inches. The angle of incidence, which means the angle of the under side of the plane when the machine is in a horizontal flying position, is 2½ degrees. The dihedral angle, or the angle which the wings assume with the horizontal, is 3 degrees, and the sweep back 5 degrees. This means that the front edge of each plane is 85 degrees. Both the dihedral and the sweep-back ansgle add to the stability of the machine when it is in the air.

The machine, including engine, water and accessories, but without fuel, weighs 1350 pounds, and the machine fully loaded 1950 pounds, including the passengers. Its maximum speed at full load is 68 miles per hour, and its minimum speed 37 miles. This low minimum speed is particularly advantageous in a training machine, as it enables the student to land at a comparatively low speed. Its range of action at economical speed is 350 miles and its gliding angle 1 in 8. This means that if the aviator is 2000 feet in the air, he can glide 16,000 feet before making a landing. This possibility gives him a range of 3 miles in picking a landing place, which is ample distance in almost every case. It also shows the safety of flying at a considerable height instead of near the earth. The machine can climb 2600 feet in 10 minutes.

It is equipped with a Hall-Scott four-cylinder water-cooled motor, rated at 90 horsepower at 1400 r.p.m. This motor weighs 410 pounds and has a 5 by 7-inch cylinder. The fuel consumption is 9½ gallons per hour, and the fuel tank holds 31 gallons. The lubricating-oil capacity in the crank case is 3 gallons. The landing gear can be readily replaced by pontoons for use over water, so that the same machine may be employed for training either army or navy students.

BUILDING THE FUSELAGE

Beginning with the construction of the frames, it is interesting to observe how they are built up from standard parts. Fig. 123 shows the two upper longerons, or side frames, placed on the assembling stands, with both the cross and the upright straps in place. These longerons are usually of ash, carefully selected and spliced in the center, owing to the difficulty of securing single pieces long enough for this work. The splice is long, with the two parts riveted together and then carefully wrapped and varnished. These splices are so securely made that they rarely give trouble or show weakness of any kind. The fuselage is built bottom side up, because the upper longerons are straight.

With all the struts, which are usually of selected spruce

FIG. 125.

FIG. 128.

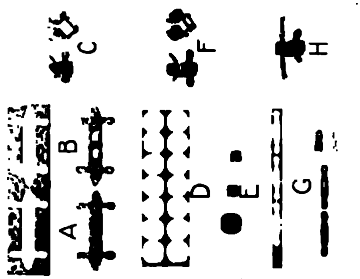


FIG. 127.

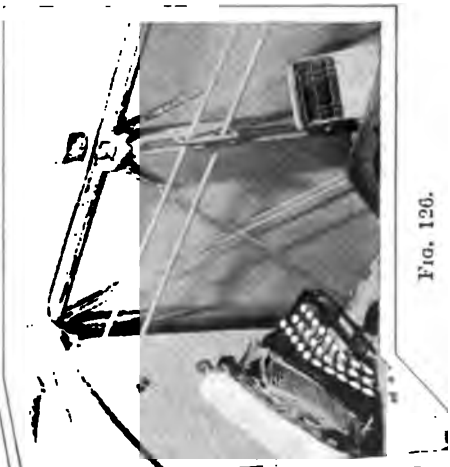


FIG. 126.

carefully made to measurement beforehand, and with the various metal fittings by which they are held in position at the proper point on the longeron, it is a comparatively easy matter to assemble this part of the fuselage. Great care, however, must be taken to have it absolutely straight with regard to a central line, as only a small deviation makes itself felt in the flying of the machine. After the vertical struts are located in their proper fittings, the curved longerons, which become the lower side of the fuselage when it is completed, are put in place with the aid of similar fittings that hold the struts in their correct position as in Fig. 124. Then the wires are put in place, each of suitable length and with its proper turnbuckle; and after all are in position, the adjustment of these various wires to their proper tension begins.

This adjusting, or tensioning, of the strut wires is a somewhat delicate operation, as each wire must be tight enough to take its proper amount of the load, but not so tight as to impose unnecessary stress on either the wires or the wooden struts. When one carefully studies the various truss wires, usually two in each panel on both the sides and the bottom, he begins to realize the possibilities of building up a light structure that shall at the same time be exceedingly strong in every direction. It is considerable of a job to have all these wires cut to proper length, and one that requires the utmost care in every particular, as the wires must not be bent too sharply nor injured in any way that will weaken them and make failures probable at that point.

Some idea of the way in which the fittings are put in place on the longerons can be had from Fig. 125. This fitting surrounds the longerons and also provides a socket for the upper end of the vertical strap; in addition, there are several ears on this fitting, to which the truss wires or their turnbuckles are attached. The illustration shows the workman tightening one of the pair of turnbuckles at this particular point. It also shows how the wires are connected to the turnbuckles and gives some idea of the crossbracing and connections for the supports shown in the foreground.

Another close view showing some of the connections is presented in Fig. 126. This is a view in the cockpit of one of these machines and shows, in addition to the fittings on the end of the straps, some of the control rods and a portable typewriter, which was being tried out. The illustration gives some idea of the care that must be taken to prevent any possible chafing between the wires and the fuel tank, which is in front. A heavy pad of soft felt may be seen between the ends of the turnbuckle and the tank, to prevent vibration from ever bringing these two points together.

It will also be noticed that lengthwise tension wires are used to insure the fittings shown being always in their proper position. These wires are connected in swiveling ears, so as to have the tension in a direct line at every joint.

Some idea of the metal fittings may be had from Fig. 127, which shows what is known as a universal fuselage fitting. The main portion of the fitting is seen blanked out at *A*, and with the holes all punched at *B*. At *C* is one of these fittings bent up into its proper shape for application on the longeron of the fuselage. At *D* is shown the blanking out of a piece that is afterward formed into a square cup, as at *E*. This cup is welded into position on the other fittings for use in certain places on the fuselage. One of these fittings is shown complete at *H*, with two cups welded in place. At *G* may be seen the blanking, perforating and bending of a swiveling piece by which turnbuckles or other connections can be connected to the fuselage fittings so as to make what is practically a universal joint, with free movement in every direction. These parts are shown in position at *H*.

As the manufacture of airplanes increases so that a large production is assured, these and other fittings will be produced much more rapidly and economically than is now possible. At the present time, the number required has not seemed to warrant the necessary expenditure for punches and dies, in order to have these pieces practically completed on the punch press. The time is not far distant, however, when this is bound to be the case, and both designers and makers of punches and dies that can be used for this purpose are sure to be in demand. Some idea of the number of these fittings and their weight can be had from the following list of parts, which are among those used in the construction of the fuselage:

	Pounds
Wire—164 feet of No. 9 aviator wire 0.037 pound per foot	6.06
120 feet of No. 10 aviator wire 0.029 pound per foot	3.48
Turnbuckles—106 at 1.25 ounce	8.28
Clevis pins—174 at 0.125 ounce	1.36
Cotter pins—174 app.	0.25
Ferrules—220 at 0.25 ounce	3.44
Lock wire—135 feet of No. 20 copper wire at 0.31 pound per 100 feet	0.42
Terminals—74 at 0.45 ounce	2.08
Fittings—38 (main)	7.25

Ball and socket fittings, of which four are used, weigh approximately 10 ounces each. Number of fittings required—approximately 65. The entire fuselage weighs approximately 160 pounds, the sheet-metal fittings forming about 7 per cent. of the total weight. The wires, turnbuckles, terminals, ferrules and clevis and cotter pins aggregate about 16 per cent. of the total weight.

After the fuselage is completely assembled, it is necessary to be sure that it is in absolute alignment in every way. A center line is run through the body and its proper alignment determined by this means. The correct tightening of all the truss wires is quite a problem and requires an especially skilled man, as each wire is tightened by sound, the different lengths of wires giving a different tone as they are vibrated. The completion of the frame includes the fastening in place of the two beams which support the motor and which are usually known as the engine bed. They are shown in Fig. 128, where the motor is being lowered into position. The front of the fuselage is braced by the

U-shaped steel support that surrounds the engine bed and ties together the whole front, or nose, of the machine.

The engine is shown in place in Fig. 129. The gasoline tank is in position, and the man at the left is putting the controlling mechanism into position. This view shows the wheel control, sometimes known as the "Dep," this wheel being mounted on an arch frame that swings back and forth and in so doing controls the movement of the elevating planes, or flippers, at the rear.

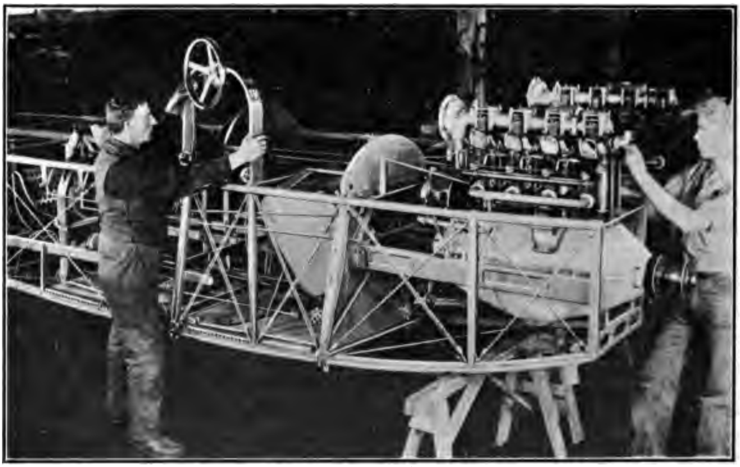


FIG. 129.—Engine in place in chassis.

Turning the wheel controls the ailerons for balancing and banking on curves.

The wings of this type of airplane are almost entirely of wood construction, as can be seen in the illustrations which follow. Fig. 130 shows the development of the ribs. They consist of three parts in addition to the top and bottom member, which comes in contact with the cloth covering. As can be seen from *A*, these ribs are first cut from fairly thick material and are then sawed into thin strips, as shown at *B*. The openings are sawed out for the sake of lightness, as at *C*, and the whole

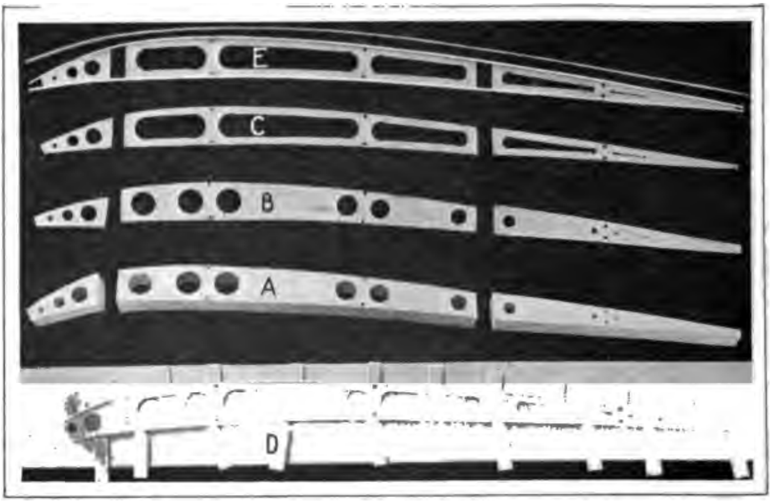


FIG. 130.—How the ribs are made.

FIG. 131.—Assembling wing with spars.

rib is assembled in a suitable fixture, as at *D*, when the top and bottom pieces are tacked and glued into place, being held by means of the small cam-shaped clamps shown. The completed rib is illustrated at *E*. These ribs are then assembled, as shown in Fig. 131, by threading over the main spars, which are clamped in their proper position at the front end while the ribs are being slid into their proper place.

Owing to the sweep back of the wings of this machine, the ribs are not at exact right angles to the spars, but make an angle of 85 degrees on one side and 95 degrees on the other. This is because the ribs must be in line with the direction of flight in order to reduce the resistance that the machine presents to the air with which it comes in contact. The wing being covered might seem to make this unnecessary, but all cloth sags a little between the ribs and leaves them a trifle higher than the plane between. This is one of the finer details to avoid resistance and skin friction.

Fig. 132 is another view of wing construction in various stages and gives a good idea of the appearance of the ribs in place on the main spar. These spars, it will be noticed, are cut away on the side so as to approach the I-beam construction as much as possible. After the ribs are properly located, they are fastened in position by small nails, and the front and rear edges are fastened in place. At the top of the front, or leading, edge is a veneer of perhaps 1/8 inch covering the upper curve of the ribs on their entering edge, in order to support the cloth thoroughly at this point. Experiments are being made in some places to eliminate this veneer as a support to the linen, but no other construction has as yet proved itself entirely successful.

A completed wing frame is shown in Fig. 133. It is an upper wing, as can be noted by the space left for the aileron at the back, or trailing, edge. It will also be observed that the cross-wing is braced with truss wires extending through the hollow ribbed construction, the finished frame being more rigid than would usually be considered possible in so light a structure of this size.

Fig. 132.—Building up the wings.

The wing is now ready to receive its linen cover, which is carefully sewed to pattern and held in position with small tacks and finally by sewing with linen thread. It is fastened with thread to each of the ribs, these seams being finally covered by a strip of linen that is held in position by the varnish, or dope, used. The application of this dope shrinks the linen tight on the frame and takes up all slackness in the covering. The final coating of dope renders the cloth absolutely waterproof and presents a solid surface to the air. Provision is made through eyelets located at the lower portion of the under side of the wing for allowing the escape of any moisture that might condense on the inside surfaces of the wing or otherwise work its way into them. A partly covered wing can be seen in Fig. 134.

The curved edges of ailerons, rudders and elevated planes are made of metal in some factories, either tubing or a specially drawn U-section being employed. In this machine, however, no metal is employed for this purpose, all the pieces forming the curved edge being built up from veneers and bent to form without seaming. Fig. 135 gives some idea of the way in which this is done.

Substantial wooden forms are provided of the proper shape for the pieces to be bent. Thin strips of the wood from which these pieces are to be formed are then put in a hot-box supplied with steam pipes and are thoroughly heated to as high a temperature as can conveniently be handled with the bare hand. These pieces, perhaps ⅛ inch thick, are then thoroughly coated with carefully prepared glue, and as many of the strips as may be required are placed one on top of the other. While the pieces are yet warm and the glue is still perfectly soft and liquid, they are placed between the forms, bent to conform with them, and the whole thing is clamped by the hand clamps, as sho When the wood and the glue have thoroughly dried, th a section of the proper shape built up of several l tions. It does not go out of shape, but has proved reliable.

Fig. 135.

Fig. 138.

Fig. 134.

Fig. 137.

Fig. 133.

In Fig. 136 can be seen several ailerons, at *A* and *B*, an elevating plane, at *C*, and a center panel, or that part of the upper wing which goes over this engine and fuselage, at *D*. This view shows the center panel mounted on horses, where it has just been covered. It also shows the spool of linen thread by which the covering is sewed, and the strips of linen cloth that are varnished in position over the stitches that hold the fabric to each rib. These strips can be seen already pasted in place on the ailerons and the elevating planes.

For covering the top of the fuselage so as to give it the streamline effect, a sheet aluminum top is put on just behind the engine. Some of these covering plates, in which are the openings for the two cockpits, can be seen in Fig. 138. Behind this aluminum top a light wooden framework is built up. It is covered with the same fabric as the wings and continues the streamline back from the metal plates. Fig. 137 shows this framework rolled up on its side, also a rudder held up in position. The short metal plates seen standing by the post, Fig. 138, form part of the covering, or hood, around the engine, the one shown being a plate for covering the forward part of the under side of the fuselage. Near this are two tanks, one for water and the other for gasoline, from which it will be seen that there is considerable sheet-metal work in the modern airplane in addition to the wooden plane and propeller and the fabric used for covering.

The edges of the cockpit are well padded and covered with either leather or some of its imitations, and the seats for the pilots are padded and covered in the same way. In this connection it is interesting to mention that there is a tendency toward extreme simplicity in the design of these seats and the upholstery that covers them, leather being no longer absolutely required except by a few governments. It is one of the many cases where specifications, as originally written, call for an article that is perhaps no more expensive than its substitute; but in too many cases these specifications are never changed, regardless of conditions that may arise. We find many instances of unnecessary expense in matters of this kind.

The struts have to be carefully made to secure maximum strength with least wind resistance. They are finished while held between centers, as shown in Fig. 139, one man shaping a

Fig. 139.—Making struts.

Fig. 140.—Covering wheels.

strut with a draw-knife and the other gaging a strut for size and contour. Fig. 140 shows how the wire wheels are covered with cloth to reduce wind resistance, a hole being left to get at the air valve of the tube, The covers are then doped to draw them tight on the wheels.

SECTION XIX

ASSEMBLING CURTISS TRAINING MACHINES

1. Packed for Shipping

The component parts of the standard JN4-B are packed for shipment in two cases. The case is designated by the name of its major contents, as:

1. Fuselage.
2. Panels.

The contents of these boxes are noted on packing sheets.

1. The fuselage contains the motor set in place; the instrument board and instruments all connected up; the carbureter control and adjustment, throttle control, spark advance control and magneto cutout switch all connected up and ready for operation; and the tail skid in place. The control bridge is in place. The leads attached to drum and wheel of bridge, for operating the ailerons, will be found wrapped around the seat rails; the leads for controlling the elevators will be found attached to the sides of the U-bridge, with ends passed through the fairleads and coiled up in the fuselage back of the pilot's seat. The rudder control wires are attached to the foot control bar, and leading to the rear end of the fuselage cover are coiled up ready for leading through the fuselage for attachment to the rudder.

The landing gear, completely assembled without the wheels, and with the cross-stay wires connected up but slack, is also packed in this case. The wheels of the landing gear, the propeller and exhaust equipment will also be found in this box.

2. The panel box contains all the panels with sockets and hinges all attached. The transverse and longitudinal wires will be found attached to the under side of the upper wing, coiled up and ready for attaching to the lower wing. The aileron control pulleys are all in place on the under side of the upper wing; the aileron control cables are passed through these pulleys and coiled up—shackles and pin at one end for attaching to the control pylons of the aileron, and turnbuckles at the other end for attaching to the "lead" coming from the control bridge and through the side of fuselage. This case also contains the elevators and rudder, with control or operating pylons removed. All the control or operating pylons for the ailerons, elevators and rudder are packed in this case. Also, all the panel struts and engine

section struts are packed in this box. The details of contents are given in the packing lists, marked "Panels."

2. Handling

In handling and hoisting these shipping boxes, care should be taken when using a sling that the center of the lift comes somewhat ahead of the center of the box. This point can be quickly determined by trial, by lifting the bridle until the box rides level.

3. Opening Boxes

The case should be placed on the ground or floor, on a firm bearing over its entire length. *Care should be taken to have the part marked "Top" uppermost.* This will avoid the possibility of wrenching the motor from its bed; also the necessity of turning the fuselage over. The top may be readily recognized by the construction: not having any metal straps tying it down. The top should be carefully pried loose with a crowbar or similar tool. Then carefully remove the side and ends of the box. The bottom side and temporary struts of the packing case are left in place under the fuselage until ready to assemble the running gear in place.

The propeller, wheels and other parts packed in this case should be removed from the members of the packing case to which they are secured.

4. Landing Gear Assembly to Fuselage

The landing gear is assembled by mounting the wheels on to the axle, and bolting wheels in place with bolts and accompanying nuts and cotters. The fuselage should now be elevated to receive the landing gear. This may be accomplished in one of two ways—either by tackle; or by shims and blocking.

(*a*) If block and tackle are used to raise the fuselage, pass a line under the engine bed supports or sills just to the rear of the radiator. To this line attach hook of block. Do NOT ATTACH LIFTING DEVICE IN ANY OTHER MANNER, TO AVOID DAMAGING OR CRUSHING SOME PART. With the fuselage now resting on its attached tail skid, lift the front end until the lower longeron clips for attachment of landing gear struts clear the landing gear. These clips on the lower longeron for connecting the front struts of the landing gear. The short bolts, with lock-washers, nuts and cotters, are in the clips attached to the bottom longerons. The lock-washers are put under the head of the bolt, and when the clips on the longerons line up with the clips on the ends of the struts of the landing gear, these bolts are passed down through the holes thus aligned. This places the nuts on the down side of the connection, thus facilitating assembling and inspection of connections. The castellated nuts are then put on the bolts and drawn up tight, until the drilled hole in the bolt is visible through the castle of the nut. Then insert cotter pin and spread the two leaves backward over the nut.

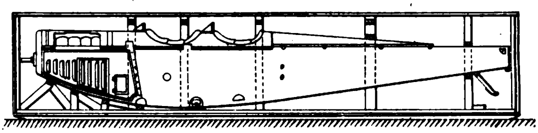


FIG. 141.

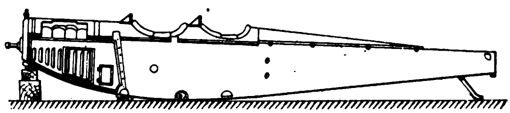


FIG. 142.

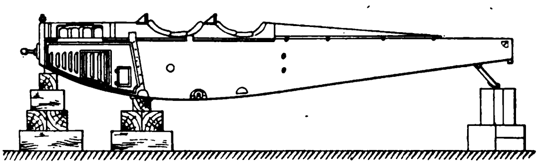


FIG. 143.

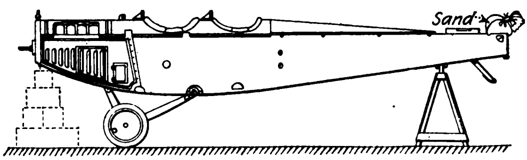


FIG. 144.

FIGS. 141 to 144.—Uncrating airplane.

This locks the nut in place. When the landing gear has been completely assembled to the fuselage, the tail of the machine should be elevated and supported by a horse and blocking until the upper longeron is level. This can be determined by placing a spirit level on the upper longeron at the tail or on the two engine bed sills (see Fig. 144).

(*b*) The other method that may be employed for raising the front end of the fuselage, to assemble the landing gear, is the following: remove the shipping blocking and front flooring of shipping case from under the fore part of the fuselage. Insert a block under the bottom longerons, thus coming ahead of the point on which the fuselage is resting, as shipped. This blocking should be aligned under the vertical strut (see Fig. 141). The flooring to the rear of the blocking should now be removed. By lowering the tail, the nose of the machine is elevated, the above-mentioned blocking serving as a fulcrum. Block up under nose of machine, placing blocking under RADIATOR-BRACKET, AND NOT UNDER RADIATOR (see Fig. 142). If the tail of the machine be now lifted, this nose blocking serves as a fulcrum, and the fuselage will clear the blocking at that point. Block up again with wedges until blocking is tight against lower longeron (see Fig. 143). By depressing tail of machine, the nose will again be elevated so that the blocking there will now need to be increased. By this alternating method of changing the fulcrum point and increasing the blocking, the nose of the machine can ultimately be blocked up sufficiently high (with tail of machine on the ground and blocking removed) that the landing gear may be assembled to fuselage, Fig. 144.

5. Horizontal Stabilizer

After the upper longeron is leveled up, the horizontal stabilizer is assembled to the tail of the fuselage as in Fig. 145. Each upper longeron has one U-bolt and four standard bolts, tied together in pairs on the under surface of the longeron by two connecting plates fastened to it. These bolts have the legs pointed upward, and serve to hold the horizontal stabilizer in place. These bolts are disposed as follows: One U-bolt secures the leading edge of the horizontal stabilizer; the four bolts arranged in pairs and engage the front beam of the horizontal stabilizer. The horizontal stabilizer is aligned over these bolts, placing the washer plate on the upper surface of the horizontal stabilizer, over the intermediate set of bolts; and the two bolts on each side of the tail post at the upper longeron level. The nuts are all drawn up tight, until the hole drilled in the bolt becomes visible through the castle in the nut, and cotter pinned.

6. Vertical Stabilizer

The vertical stabilizer is now fastened to the horizontal stabilizer:

1. By means of the bolts which pass through the forward and after parts of the horizontal stabilizer, and

2. By means of the flexible stay lines running from the top of the vertical stabilizer to the upper surface of the horizontal stabilizer. The forward bolts pass through the clip at the lower front point of the vertical stabilizer.

The bolts which are fastened to the tail post of the fuselage, and engage the after end of the horizontal stabilizer, also engage the lugs fastened to the bottom edge of the vertical stabilizer at the rear. Draw the nuts up tight and lock with cotter pins. The flexible wire cables, attached to the vertical stabilizer, and turnbuckles are used to align and tie down the vertical stabilizer.

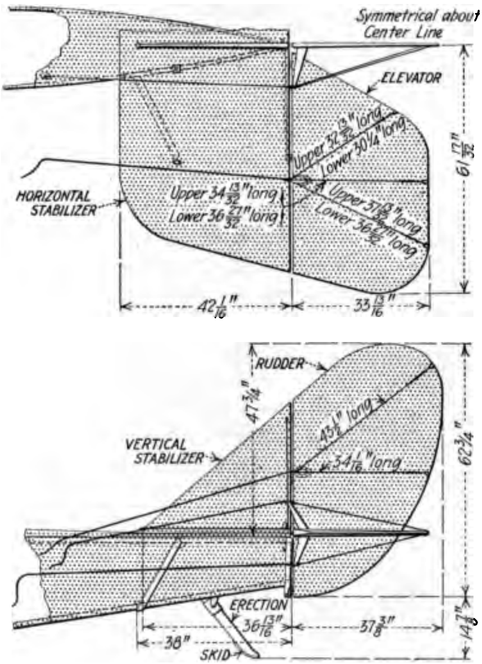


Fig. 145.

7. Rudder

The control pylons or braces are first attached to the rudder. These braces are so placed that the upper tips point toward the hinge line. In this fashion the holes will match up. The bolts and nuts for securing braces to the rudder are shipped and fastened to the braces. Before mounting the rudder the vertical stabilizer should be checked up, so that it is in plumb alignment with the tail post. This check is absolutely necessary to insure the absolute alignment of the hinges in the vertical stabilizer and the tail post. The rudder is now mounted onto the tail post and vertical stabilizer by means of the hinges. The hinge pins are now inserted in the hinges, and cotter pins passed through the drilled holes in the bottom of the pins. The cotter pins should be spread backward as usual.

8. Elevators

These are first equipped with the control braces which, with the accompanying bolts, nuts and cotters, are found in the Wing Panel Packing Box.

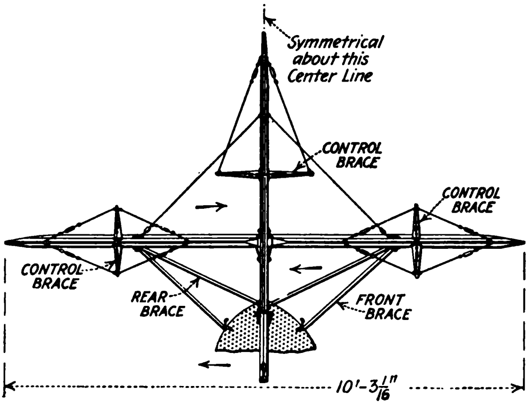


Fig. 146.

The position of the base of the control brace is indicated in Fig. 146. These braces are also arranged so that the upper tips point toward the hinge line. The elevators are mounted to the horizontal stabilizer by means of the hinges and hinge pins. The hinge pins are kept in their bearings by the cotter pins, inserted through the drilled holes in the bottom of the hinge pins. The position of the elevators are also shown in Figs. 145 and 146.

9. Panel Assembly

The panels are now to be assembled. Before the main panels can be connected to the fuselage, the engine section panel must be erected.

Engine Section Panel.—The engine section struts are set into place into their sockets on the upper longerons. These posts are found packed in the

"Panel" box. The forward posts are approximately held in place by the flexible wire lines to be found coiled up and temporarily fastened under the cowl in the motor compartment. The rear struts are approximately held in place by the flexible wire lines leading from the lower longeron and will be found coiled up under the aft-cowl. The engine section panel is now mounted on the struts, after the front transverse bracing, between the posts, is approximately trued up. The engine section panel posts and wires are then trued up prior to further erection. This condition is obtained by adjusting all "mated" or similar wires to the same length.

10. Main Panels

The main panels are now to be assembled to the machine. There are two methods for accomplishing this:

(*a*) Assemble panels, struts and wires, before attaching to fuselage.

(*b*) Assemble the upper plane to the engine section, and complete assembly.

The first method is the most advantageous, since it permits the setting of the main panels at the approximately correct stagger and dihedral, and does not require as much subsequent adjustment as the second method.

(A) First Method—Wings Completely Assembled

All the main struts will be found to bear a number. These numbers run from 1 to 8. The method used in numbering the posts is as follows: Starting as post No. 1, with the outer post on the left hand side of the pilot, as he faces his direction of travel, the front posts are numbered successively from

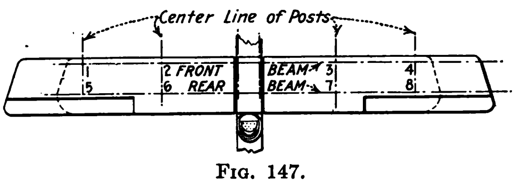


Fig. 147.

No. 1 to No. 4: Nos. 1 and 2 being on the left side and Nos. 3 and 4 being on the right side. The rear posts are similarly numbered from No. 5 to 8: Nos. 5 and 6 being on the left and Nos. 7 and 8 being on the right. This system of numbering does not include the engine section struts. Fig. 147 shows the system graphically.

The system of marking also insures that the struts are not inverted in their sockets. This is accomplished by painting the number on the strut, so that when viewed from the pilot's seat all numbers can be read; *i.e.*, the numbers are painted on that side of the strut intended to face the fuselage, as diagrammatically shown in Fig. 147. If a strut be inverted by mistake, it can thus quickly be detected.

1. The upper left wing panel is first equipped with the front and rear masts by inserting the masts into their sockets on the upper surface of the panel. The mast wires are then connected up to the anchor plates, located on the upper surface to the right and left of the mast-socket. Adjust the tension in these wires, by means of turnbuckles, until the front and rear wing beams become straight.

2. Stand the upper left wing panel and lower left wing panel on their "leading" or "entering" edges, properly supporting the panels in cushioned blocks to prevent damage to the nose. Space the panels apart, approximately equal to the length of the struts.

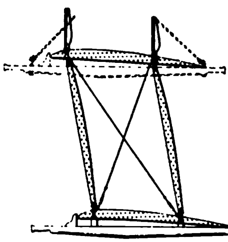


Fig. 148.

3. Next connect up the diagonal cross wires. These must be loosely connected up (by loosening up the turnbuckles), to permit the easy entering of the posts into the sockets. The wires are connected before the posts or struts are set in place, since, with the latter in place, the connecting of the wires to the lugs of the sockets is accomplished only with difficulty. After these wires are thus connected, insert the posts and bolts into place.

4. Connect up loosely the "landing" (single) wires and "flying" (double) wires of the outer bay to hold the wings together as a unit. The outer bay is thus completely wired, though but loosely.

5. The posts that are used for this left side are, according to the diagram, No. 1, No. 2, No. 5 and No. 6. No. 1 is the outer front; No. 2 the inner front; No. 5 is the outer rear; No. 6 the inner rear.

6. The wings, as above assembled, are now erected to the fuselage. Extreme care should be exercised in transferring the wings to the fuselage, not to strain or break them. In carrying the wings, use wooden boards placed under the wings, and block up under the wing beams (which can be easily located by the line of fittings attached) so that these take the strain of the

load. Do not attempt handling assembled wings, using the posts as carriers, or by attachments to the trailing or leading edges. Fig. 148 shows a good manner in which the panels may be shifted.

The wings should be firmly supported temporarily by a suitable sling at the upper outer post point (not beyond this point), or by a horse, properly blocked under lower wing at outer lower post point (not beyond this point), during fitting of wing to machine. See Fig. 149 for arrangement. The

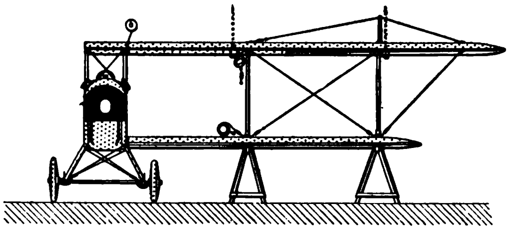


FIG. 149.

wings will have the approximate stagger if assembled as above, since the posts are in place and the tension cross wires are adjusted to almost correct length when shipped. Insert the hinge pins through the hinges, located at 1 Fig. 149, as now coupled up.

7. *Adjustment for Dihedral.*—The fuselage must now be leveled up transversely and longitudinally. A spirit level placed across the two engine-bed supports will determine the transverse condition. With the level placed fore and aft on the longerons, or on the engine beds, the longitudinal level is established.

8. Adjust the tension on the flying and landing wires until the dihedral of 1 degree is established, also to make the leading and trailing edges parallel

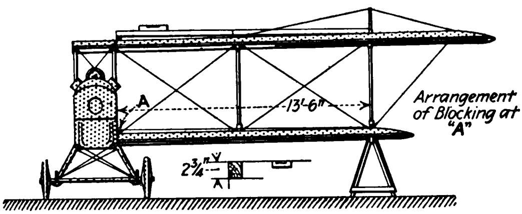


FIG. 150.

and straight. The amount of lift for the 1-degree dihedral is 2¾ inches in 13 feet 6 inches (distance from the inner edge of the panel to the center-line outer post). An easy method for checking the correct adjustment of th dihedral is to place a block 2¾ inches high on the upper surface of the lower wing, at the extreme inner edge. A straight edge resting on this block and on the upper surface of the wing (straight edge kept parallel to front or rear beam) should be level, Fig. 150.

This may also be checked by using a light spirit level, suspended from a string stretched over the given range. If a block 2¾ inches high be clamped to the inner edge of the panel, and a line pulled taut from this block to the center line of the outer beam, the level suspended next to the block will be sufficiently sensitive to determine the required degree of dihedral. Fig. 150 shows the arrangement diagrammatically.

If the outer end of the wings is too high, the landing (single) wires are too short and the flying (double) wires are too long. Hence, loosensing up equally on the inner and outer, front and rear flying (double) wires, will correct this condition. If the panels are too low (dihedral not up to 1 degree), reversing the above method correct this condition.

9. *Adjustment for Stagger.*—The tension in the longitudinal cross wires is now adjusted for stagger. The distance between a plumb line dropped from the leading edge of the upper wing and the leading edge of the lower

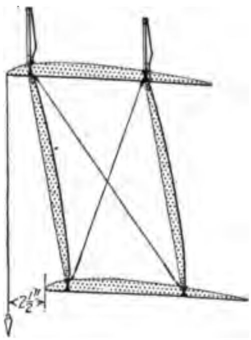


Fig. 151.

wing should be 12⁵⁄₁₆ inches. If the amount is less than 12⁵⁄₁₆ inches, the line leading from the lower wing front socket to the upper wing rear socket is too long. Hence, drawing up on this line and lengthening out on the cross line will correct this condition. If the distance is more than 12⁵⁄₁₆ inches, reverse connections of wire lengths (see Fig. 151).

10. Check up the dihedral to see if this has been disturbed while setting stagger. Also check up with eye the alignment of the front and rear beam, and parallelism of leading and trailing edges. If these are not parallel, adjustment of the landing (single) wires in the inner bay (next to fuselage) will generally correct this condition.

11. The wing skids on the under side of the lower wing should now be fastened to the sockets, directly under the outer posts.

12. Bend all cotter pins out, and lock turnbuckles with safety wires. This latter is accomplished by first passing a soft wire through the eye of one shank of the turnbuckle, then winding the wire four to five times about the shank, the shorter, loose end of the wire being wrapped under the windings; then pass the free end through the small hole in the center of the barrel, then through the eye of the opposite shank, wrapping this free end around this shank and wire. This effectively locks the turnbuckles.

13. The other side of the machine (right side) is then assembled in the same manner.

(B) Second Method of Erecting Panels

The following outline method is given; the details of handling and adjusting of wires are identical with the details given for the first method:

1. Insert masts (cabanes) into sockets and connect mast wires to anchor terminals. Adjust tension of mast wires until beams are straight.
2. Connect upper panel to engine section and bolt upper end of struts into fittings.
3. Jack up wing tip of upper panel so that lower panel can be connected.
4. Connect lower panel to fuselage.
5. Connect across diagonal wires.
6. Bolt lower ends of struts into fittings on lower wing.
7. Connect landing (single) wires.
8. Connect flying (double) wires.
9. Proceed in like manner with other side of machine.
10. Remove jacks and level fuselage longitudinally and transversely.
11. Adjust tension on landing (single) and flying (double) wires until the dihedral is 1 degree; leading and trailing edges are parallel and straight.
12. Adjust tension on diagonal wires until stagger is 12$\frac{5}{16}$ inches.
13. Attach wing skids.
14. Bend cotter pins and safety wire turnbuckles.

11. Aileron Adjustment

Attach both ailerons (one on each side of machine, after having mounted control braces to ailerons) and fasten pins of hinges with the necessary cotter pins. Temporarily support ailerons so that their *trailing edges* are 1 inch *below* the trailing edges of the upper panels. Then connect up the flexible tie-line that, passing over the top of the upper wings, through fairleads, is connected at the center by a turnbuckle, and, passing through pulleys attached to the upper surface, front beam, is attached (by shackle and pin) to the upper control brace of the aileron. This "lead" is allowed, so that when in flight, the force of the lift will somewhat raise *both* ailerons and bring their trailing edges on a line with the trailing edges of the panels. Now lead the end of the aileron control line attached to bridge through the hole in each side of the fuselage (between front and rear seats). Uncoil the connecting line which passes over the pulley attached to the lower surface of the upper wing, near the front outer post. Attach shackle and pin end to lower control brace of aileron, and attach turnbuckle end to loop of aileron control lead attached to bridge (and which passes through side of fuselage). In making this last attachment, the leads should be so arranged (by moving the wheel on the bridge) that the lengths projecting through the fuselage are equal.

12. Rudder Control Adjustment

Uncoil the lines attached to the rudder bar, to lead out through the upper surface of the rear end of the fuselage cover, and, keeping the rudder control bar at right angles to the longitudinal axis of the machine, fasten the ends ot the control braces. Next take up the slack of the lines, by means of the turnbuckles, adjusting the tension equally in each set; the rudder control bar (foot control bar) should remain at right angles to the longitudinal axis, when the rudder is neutral (or in a vertical plane through this fore and aft axis).

13. Elevator Control Adjustment

Temporarily maintain the elevators in the plane of the horizontal stabilizer (neutral position). Move the U-bridge, Fig. 152, forward until the distance between the instrument board and the nearer surface of the tube of the bridge is 9 inches. By fixing this distance from the instrument board or dash to the back of the bridge, a slight lead is given to the control, for the greater range for raising the elevators. Now uncoil the wires leading from the clips attached to the sides of the bridge, and coiled up aft the pilot's seat. Pass the wire attached to the lower clips out through the side of the fuselage, through the lower of the two vertical holes, aft of the pilot's seat. With the bridge lashed, or fastened to the 9-inch position, connect this wire to the upper control brace of the elevator. Repeat operation for other side of machine.

Similarly the wire attached to upper clip on U-bridge is passed through the upper hole in fuselage side, and attached to the lower control brace of the elevator. Fasten the flexible tubing fairleads on the upper brace control wire to the leading edge of the horizontal stabilizer. Fig. 152 shows the general arrangement of the controls. Adjust tension in these wires, by

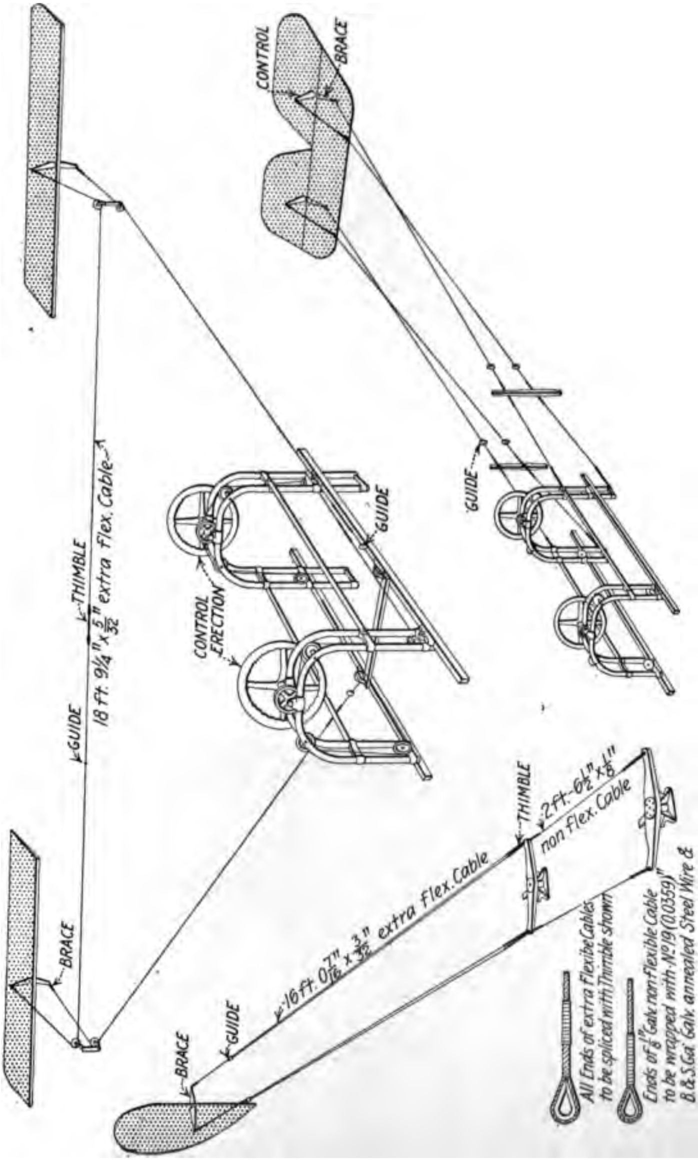

CONTROL
BRACE
GUIDE
GUIDE
CONTROL
ERECTION
THIMBLE
18 ft. 9¼" x 5/32" extra Flex. Cable
GUIDE
BRACE
BRACE
GUIDE
16 ft. 0 7/16" x 3/32" extra flex. Cable
THIMBLE
2 ft.-6½" x 1/8"
non flex. Cable
All Ends of extra Flexibe Cables to be spliced with Thimble shown
Ends of 1/8" Galv. non Flexible Cable to be wrapped with No. 19 (0.0359)" B.&S.Ga. Galv. annealed Steel Wire & Soldered

Fig. 152

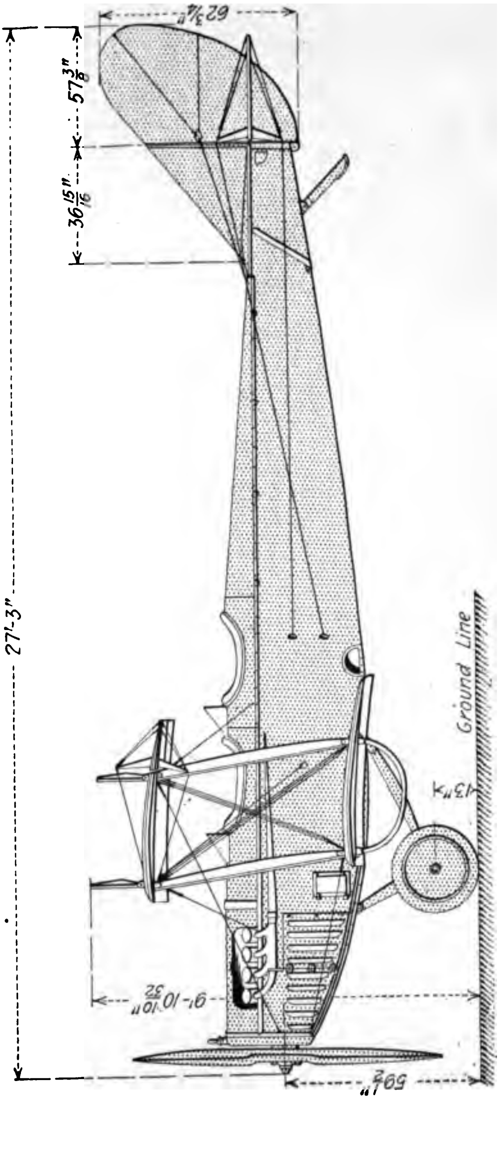


Fig. 153.

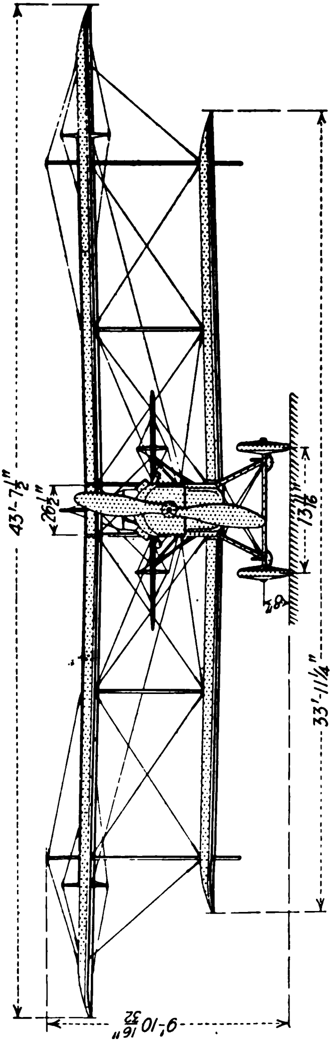


FIG. 154.

means of turnbuckles, so that all lines have the same degree of tautness. The elevators will then be neutral for this position of the bridge.

Figs. 154 and 155 show side and front views of the assembled machine.

14. General

All connections having now been made, carefully go over each shackle, pin and turnbuckle, and see that all pins are properly in place, all nuts on bolts tight, and all cotter-pinned. Try out all controls for action and freedom of movement. See that no brace wires are slack, yet not so taut that, when plucked, they "sing."

Attach nose wires leading from nose of machine to intermediate posts, front and rear. The lower wire connects up with the lower front socket, on the upper surface of the lower panel; the upper wire connects up with the upper-rear socket plate on the under side of the upper panel, after the panels are attahced to fuselage, with stagger and dihedral properly corrected.

SECTION XX

GENERAL DIMENSIONS OF TRAINING MACHINES

A good idea of the general dimensions of training machines may be had from the illustrations in Figs. 155 to 158 inclusive. This shows a slightly modified Curtiss machine which has proved very successful in preliminary training work.

The large side view, Fig. 155, shows the general appearance of the machine and gives its main dimensions.

The appearance of the machine from the front, together with the leading dimensions, is shown in Fig. 156, while a top view, showing the position and proportion of the ailerons, is given in Fig. 157.

The British and Canadian fliers prefer the "stick" control, as shown in Fig. 158, to the wheel or "Dep" control, for all except the heaviest machines. The details of this control, as installed on the dual, or double control machines, is clearly shown and its operation can be easily traced.

A fore-and-aft movement of either stick controls the elevators by which the machine is made to either ascend or descend. A side movement of the stick operates the ailerons and maintains the balance or aids in turning by preventing skidding and side slip. Steering is done by the foot bar shown.

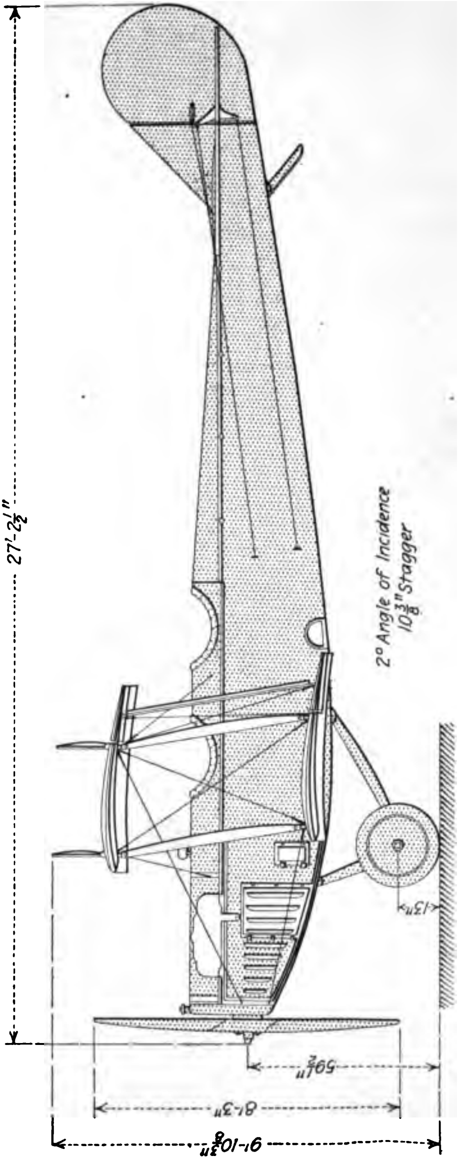


Fig. 155.

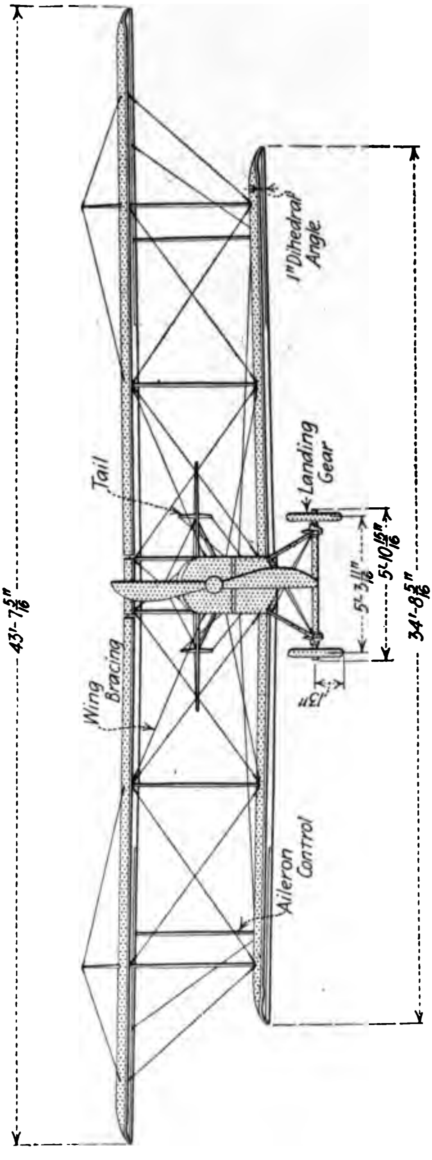
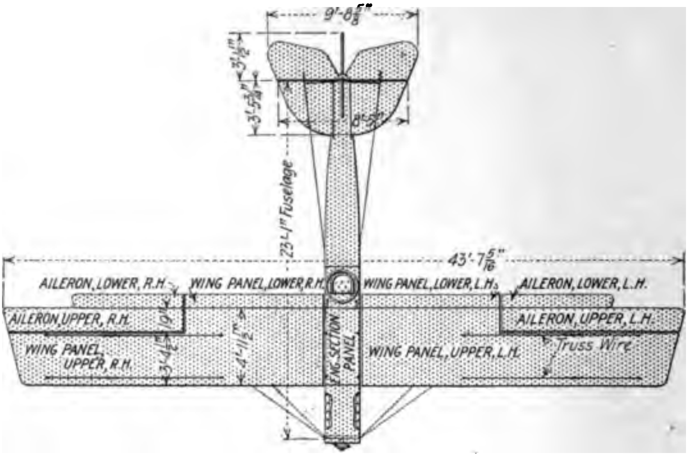

43'-7 5/16"
1" Dihedral Angle
Tail
Landing Gear
5'-3 11/16"
5'-10 15/16"
34'-8 5/16"
12"
Wing Bracing
Aileron Control

Fig. 156.



23'-1" Fuselage
43'-7 5/16"
AILERON, LOWER, R.H.
WING PANEL, LOWER, R.H.
WING PANEL, LOWER, L.H.
AILERON, LOWER, L.H.
AILERON, UPPER, R.H.
AILERON, UPPER, L.H.
WING PANEL, UPPER, R.H.
WING PANEL, UPPER, L.H.
WING SECTION PANEL
Truss Wire

Fig. 157.

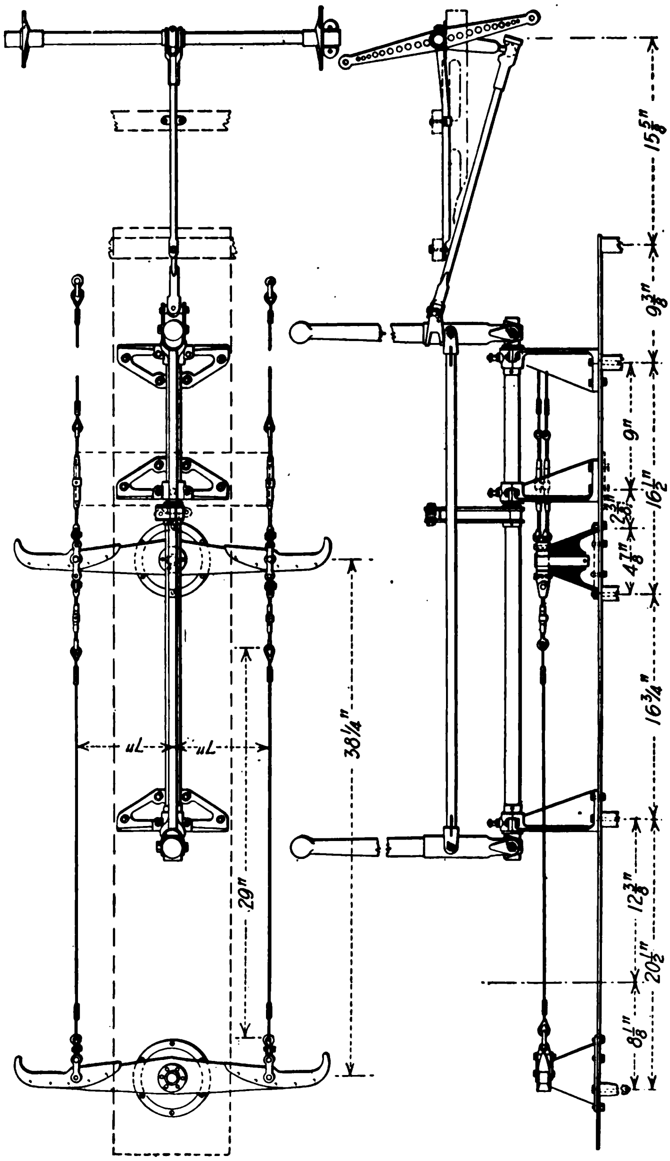


FIG. 158.

SECTION XXI

HOW THE "EYES" OF THE ARMY WORK

We read of the airplane being the eyes of the army, but few of us realize what this really means. The old methods of observation from some high point or even from a captive balloon are next to impossible in this greatest of all wars, as the balloon stands very little chance against the swift airplane, either in direct attack or in giving the range to the gunners by wireless. Consequently it is extremely interesting to know how these modern eyes do their work.

Everything is timed, and timed accurately, from a predetermined hour, which is known as the "zero of the day." This zero may be at any hour or fraction of an hour set by the commander. This plan renders it extremely difficult for any spy to get information to the enemy, even if he knows the orders; for unless he also knows the zero from which the operations are all timed, the information would be of little value.

When a battery commander desires accurate information as to any object he wishes to shell, he communicates with his air base. Then a spotting plane, carrying an observer, goes up at the proper time to a height of 15,000 feet, this being the usual observation height at present. The climb may take 30 minutes, for these spotting planes are not of the fastest and are not fighting machines in many cases. Having reached the 15,000-foot level, the pilot guides his machine in long ovals, or elongated letter O's, over the place the gunners want to reach. He arranges his ovals so that the long side of the letter O is in the direction of the wind. This procedure enables the observer to make his observation while the plane is at its slow speed in going against the wind and to utilize the other part of the oval for sending his wireless messages to the gun commander. In this way the gunner is kept constantly informed as to each shot, if it be long-range work, and the spotting plane often stays in the air for 2 or 3 hours while a certain position is being demolished, to be called down at the discretion of the commander, if it is not forced down.

USING CAMERAS TO LOCATE HIDDEN BATTERIES

But this work of observation is not as easy as the description may sound. With carefully concealed batteries, it is very difficult to locate them accurately from such a height, which is nearly 3 miles: The observer is furnished with maps of the country, which are made in most cases from previous photographs taken by other observers. With these as a guide, the observer takes many photographs with a special camera, either through the bottom of the plane or over the side. These cameras have lenses of three different focal lengths, 20, 50 and 120 centimeters, to be used in accordance with the work in hand. The shorter-focus camera naturally takes a very wide angle with a correspondingly small object and may not discover the thing desired, which is the hidden battery that is keeping quiet to avoid revealing its position. Then the second lens is tried, giving a field of about 800 square feet at the height of 15,000 feet. It is the lens most used for this plotting work. By taking photographs that lap over each other, a very complete topography may be worked out. If the hidden battery is not shown, the longest lens is used, which greatly enlarges the size of the object and usually allows the enemy's guns to be picked out.

Should this fail, however, as happened at Ypres, where a battery of big guns were screened with wonderful care and could not be discovered even with the long-focus lens, the most dangerous work of the aviator becomes necessary. This task consists in flying low enough to allow the observer to pick out the battery with powerful field glasses. When we realize that anti-aircraft guns sometimes bother a man at 12,000 feet and even higher, the hazard entailed in flying as low as 2000 feet, or even lower at times, can be understood. Yet this feat sometimes becomes necessary, even at the loss of one or more machines; for if the guns are not discovered and silenced, it may entail the loss of hundreds of troops and may mean the failure to capture a certain position.

So carefully is this work of plotting done and so many are the photographs taken in important sections of the front that the observer becomes so familiar with the country and its inhabitants that he can pick out certain dots that he knows are men; and he can tell what the person is doing and where he is going, assuming of course that he is pursuing his regular tasks.

Just as the presence of our "spotter" over the enemy is of great value to our side, so is it correspondingly injurious to the other; and the fast fighting planes of the enemy try to drive him down in order that the artillery may not have this deadly and accurate eye over their positions. To protect the aviator at his post, the fast fighting machines of his own army often fly high above the spotting plane, so as to be able to swoop down on an enemy before he can disturb the spotter. It is these encounters, protecting one's own spotters and driving down the spotters of the enemy, which give the real air battles and which outrival the wildest fancies of the great dreamer of years ago, Jules Verne. Some of these battles are almost unbelievable and will form some of the most thrilling anecdotes of the war.

SECTION XXII

THE CANADIAN TRAINING CAMP AT BORDEN

The airdrome, or flying field, at Camp Hoare, which adjoins the infantry camp at Camp Borden, Ontario, Canada, is an excellent example of what can be done to develop a flying field quickly when necessity requires. This particular tract of about 840 acres is located in a country in which a sandy soil predominates and was covered with hundreds of trees and stumps when the first steps were taken to convert it into a flying field. The first engineers arrived early in February of this year, when there was 3 feet of snow on the ground and the temperature was hovering around 20° below zero.

The stumps were pulled out, the ground was leveled into comparative smoothness, and flying commenced in 2 months' time. This involved more than the clearing of the field, for hangars, machine shops, offices, commodious quarters for the students and officers, mess halls and cheerful reading and lounging rooms had to be erected. Relaxation is as necessary as strenuous application in the study and practice of the airman's art. Furthermore, grass has been coaxed into existence over nearly the entire field.

There are 15 hangars, each accommodating six machines and containing one room for stores and another for clothing and fittings for the students assigned to that hangar. There are also offices for each squadron where all records are kept, as well as the general field office and various instruction rooms where the intricacies of the airplane engine, the machine gun, air photography, mapping, directing battery fire, wireless and the various activities with which the modern military aviator must be familiar are taught. Repair shops for engines and planes—for salvaging whatever may be usable from wrecks—a blacksmith shop, testing stands, and gasoline storage and garages go to make up the interesting whole.

Each of the 15 hangars (one of which is shown in the heading illustration) is 120 by 66 feet and is made with latticed wooden roof trusses that span the whole structure so as to leave the interior free for the accommodation of machines. The hangars cover a space of about ¾ mile on one side of the flying field. Back of these, separated by a concrete road, are the shops, offices, garages, technical stores, instruction rooms, etc. The quarters for the officers, students and mechanics are perhaps ½ or ¾ mile away, so as to make the relaxation as complete as possible. Furthermore, as far as possible, shop talk is tabooed from the table and lounging rooms.

EACH SQUADRON HAS 18 MACHINES

Each squadron consists of 18 machines, and consequently occupies three hangars. Each six machines is known as a "flight." There are five squadrons to this field, making 90 machines all told, of which about 60 per cent. are kept in commission at all times. Each squadron is composed of about 150 students, or cadets, who are graduated as they become proficient and are then ready to go overseas for additional training on the types of machines used on the battle front. These men leave in classes or groups of 25 or 30, at the discretion of the commanding officer, so that there are always new and old students at the field, affording new students the benefit of observing those who have had more experience.

The five squadrons at Camp Hoare require a total of about 720 men, 150 of whom are the mechanics employed in the repairs divisions. Each squadron has its trained group under a leader, who may be called a foreman with the title of corporal. The men in each group dismantle wrecked machines, take off and replace wings or other parts, get the machines to the repair shops or hangars and otherwise assist in keeping the machines of their squadron in flying condition.

The way in which these men handle damaged parts shows the training they have had as well as their adaptability in new lines of endeavor, for only a few of them were skilled in this work previous to their enlistment. A few are from English fields, while a still smaller number have seen service behind the fighting lines in France and so know exactly what the conditions are at the front. These men assist greatly in the training of new men and are doubtless largely responsible for the systematic manner in which the work is handled at the camp.

SOME OF THE "CRASHES"

Two typical training-camp "crashes" are shown in Figs. 159 and 160, and the way in which the wrecking crew gets to work

FIG. 159.

reminds one of the men at the repair pits in a long-distance automobile race. Every man knows his particular job and starts to work as soon as he reaches the machine. These crashes are nearly always the result of poor landings rather than of falls due to engine failure or losing control of the machine in the air. On this account the breakages are comparatively light, although considerable damage is done in any case, as can be seen from the illustrations. In making a bad landing the front

Fig. 160.

end of the machine usually drops; the wheels strike the ground with enough force to crumple the struts that go from the axle to the fuselage or body, the wheels are forced back under the

Fig. 161.

lower planes and damage them in some way or other, the propeller, or "prop," as it is called for short, digs into the ground and breaks off, and the whole thing looks much more badly damaged than is actually the case. Fig. 161 shows the wheels driven back under the planes.

As soon as a machine strikes the ground the crew starts after it with a repair kit, and in a few minutes the wings are off, as

Fig. 162.

in Fig. 162, and the machine is on its way to the hangar, unless the damage is unusually serious. Generally the wheels do not crumple, so they can be used as a truck for rolling the machine

Fig. 163.

across the field, as in Fig. 163. If the landing has had enough sidewise motion to crumple the wheels, but not enough to seriously damage the axle, new wheels can be put on for rolling the air. On this account the breakages are comparatively light, although considerable damage is done in any case, as can be seen from the illustrations. In making a bad landing the front

Fig. 160.

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As soon as a machine strikes the ground the crew starts after it with a repair kit, and in a few minutes the wings are off, as

FIG. 162.

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FIG. 163.

across the field, as in Fig. 163. If the landing has had enough sidewise motion to crumple the wheels, but not enough to seriously damage the axle, new wheels can be put on for rolling the machine; but if this cannot be done, a truck that is attached to each squadron goes after the machine and carts it to the hangar.

THE MOTOR TRANSPORT NEEDED

Each squadron has a transport unit of its own, housed in a garage behind its section of the hangars, consisting of one Packard motor truck of 3-ton capacity, two light tenders (Studebaker six-cylinder chassis with a side-seated body to carry eight or ten men), two Indian motorcycles and one side car. In case a machine has to make a forced landing outside the airdrome and suffers some damage doing so, the squadron commander is notified, and he dispatches the truck with such parts as may be needed to make repairs in the field together with a tender and enough men to do the work. In case the machine cannot be repaired, the men dismantle it, load it on the truck and carry it back to the hangar, repair shop or salvage shop, depending on its condition.

Fig. 164.

The training machines weigh about 2000 pounds, much of this weight being at the front, so that when it becomes necessary to put the fuselage, or frame, on a truck considerable lifting has to be done. An instance of this is shown in Fig. 164, where the fuselage was broken in landing, as were also the lower planes and the propeller. After removing the wings, the truck was brought on the field and backed into position in front of the engine. Then, while the front was being lifted by the aid of scantlings laid under the engine, the truck was backed under carefully and the front of the fuselage loaded on the truck. The rear end, with its undamaged rudder, stabilizers and elevating planes, was kept off the ground, the remains being taken to the hangar for further dismantling. In this instance the fuselage was a total wreck, though the engine was not seriously damaged.

After the engine and such of the rear end as is seen to be undamaged are removed, the rest goes to the salvage shop for com-

Fig. 165.

Fig. 166.

plete dismantling. The turnbuckles, the cables with their eyes and loops and all small parts which are usable or which have scrap value are saved and put into special bins. Planes that can be repaired go to the wing shop, and if only one longeron or main frame piece of the fuselage is broken, the frame can be repaired by putting in a new piece or part of a piece, as shown in Fig. 165.

If a main spar is broken in a wing, it is not considered advisable to attempt a repair, as when a wing has had sufficient shock to break a spar it is more than likely that all the other members have been stressed beyond the safety point. Radiators are liable to be damaged in crashes of almost any kind, an example of this being shown in Fig. 166, where the plane fell quite a distance. Fortunately there were no fatalities. For such repairs as can be made, a part of the blacksmith shop is fitted with sheet-metal shears, rolls and soldering apparatus, as well as an oxyacetylene welding and brazing outfit for such cutting and welding as may be necessary. There is also a tire vulcanizer, as the problem of keeping pneumatic tires and tubes in good condition is very serious at times. As with the automobile, nothing has yet been

Fig. 167.

found, that equals an air cushion between the earth and the machine such as furnished by tires.

After 50 hours in the air (an accurate record is kept of every plane and every engine), the engine is examined without taking it out of the machine. Every cylinder is taken off, the pistons are scrutinized, the play in the piston and crankpin is noted, the carbon is scraped from the pistons and cylinders, the valves are ground, and the engine is put in good shape for further running. Fig. 167 shows this being done and also the manner in which the parts are kept separate in the box on the floor. After 100 to 150 hours, if nothing else has happened to make repairs necessary, the engine is removed from the machine, taken to the engine repair shop and thoroughly overhauled. This includes taking off connecting rods to examine bearings, replacing with new metal if necessary (which is nearly always the case), examining for connecting-rod cracks, installing new piston rings should these be required and, in fact, putting the engine in practically as good condition as when new.

FIG. 168.

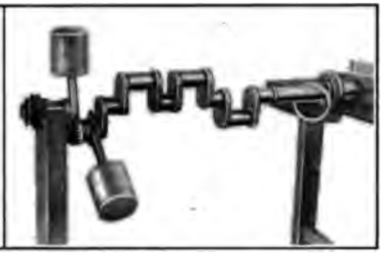


FIG. 169.

For holding the engines, instead of the revolving stands such as are used in the factories where they are built, the engine base is bolted to two substantial wood strips, about 2 by 3, with the ends projecting sufficiently to hold them on frames at each end. These sticks have handles on the ends, thus making it easy to shift the engines from one position to another (see Fig. 168) for the convenience of the workman.

One of the dangers of a forced landing, with the attendant crash, is the bending of the engine crankshaft when the propeller strikes the ground or the engine itself noses into the earth too deeply. When this occurs the engine is sent to the main repair shops in Toronto, where there are facilities for straightening the shafts and putting them in shape again. Where the shaft is not bent and the repairs can be made at Camp Hoare, the rods are fitted with the crankshaft held as shown in Fig. 169. This is a simple clamping device placed on the bench, for holding the shaft from turning while the outer end is supported as shown. In this way it is much easier to fit the rods than if the shaft was on the bench, as the rods may be swung all the way around the shaft so as to feel the fit in all positions. It is one of the little shop devices that make for quicker and easier work.

FEW ENGINE FAILURES

The motor shop has ten benches and a small machine equipment, this being ample to keep 90 machines in operation as far as the engine end is concerned. From the motor shop the reassembled engine goes to the testing stand, Fig. 170, behind the blacksmith shop, being rolled out on a pair of landing wheels connected by an axle and constituting a very simple truck for the purpose. The engine is run on the stand for a half hour and is then put back into service. It is gratifying to note that engine failures are few and far between, although constant care is necessary to maintain magnetos, spark plugs and similar parts at maximum efficiency so there will be no failure while in the air.

The landing wheels are of wire and weigh much less than might be supposed. They are covered with cloth to reduce wind resistance while in the air, this covering being put on in the shape of cloth discs that come over the edge of the rim. These discs, in addition to being cemented to the rim, are held by the bead of the clincher tires used. The wheels, before and after covering, are shown in Fig. 171.

To maintain the supply of wheels for a training camp is something of a problem, as the number of breakages, or such damage as puts a wheel or tire temporarily out of commission, varies within wide limits. In 1 month, for example, only 20 wheels were required to keep all the available machines of one squadron in commission for 800 flying hours. In the first 7 days of the

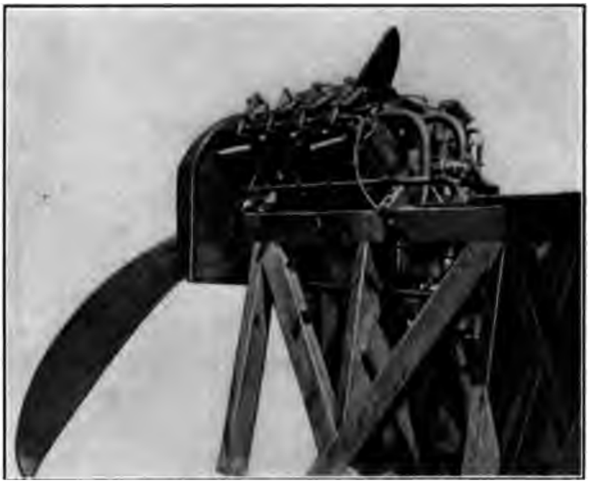


Fig. 170.

next month 24 wheels were used during 250 flying hours, an epidemic of bad landings being responsible for the difference. As about 60 per cent. of the machines are in commission on the

Fig. 171.

average, this means only two wheels each a month in the first case and about ten wheels per machine for the next month.

KEEPING ACCURATE RECORDS

It is important in a training camp to maintain accurate and adequate records, and the way in which this is done at Camp Hoare is impressive in its thoroughness and completeness. Each squadron commander keeps an accurate record of the performance of each man and each machine in his charge. Every flight is recorded, from the time a man leaves the ground till he returns, and the data are credited both to the man and to the machine. Every hour the engine runs is recorded, both to insure its being oiled at the proper time and to prevent it from being run for more than 50 hours before undergoing the first examination. After 12 hours of running, the oil is emptied from the crank case and new oil put in its place. This record is kept in each hangar for the machines that belong there, a board with small clock dials and suitable hands being used for this purpose.

The engine repair shop keeps it record of repairs and of the progress of these repairs on a board fitted with hooks and metal discs. There is a column for each step in the repair work and sufficient room to show all the engines that can be sent through the shop at one time. The discs are colored differently on the two sides, the light side indicating that nothing has been done or that the work is not completed, while the dark side appearing in any column shows that this portion of work has been completed. In this way the status of any engine in the shop can be readily known at a glance. From a survey of the board it can be seen what engines are behind for one reason or another, and men can be taken from one engine to hurry another along should this be deemed desirable for any reason.

The various records are summarized in the office of the commanding officer, Major O. D. Filley, in such a way that he can tell almost at a glance the condition of the entire equipment. Covering one side of his office is a rack that reminds one of the system employed in many railroad shops to show the condition of the locomotives or rolling stock as well as its disposition along the many divisions of the road. Among other information the board shows the condition of every airplane in the camp, whether it is in flying condition or whether its idleness is caused by the engine or the plane not being ready. It shows the progress of each student and just what part of his course of instruction he is engaged in, and gives the commanding officer a general idea of the work of the entire camp.

Charts on the side walls give summaries of the total hours flown at the school each day, week and month, the work done by each squadron and each student, and such other information as helps in the planning of instruction and mechanical details. Records are also kept of each cadet's performance in wireless, in directing gunfire, in photographing prominent positions on the earth, in handling the machine gun in the air and all the other articles with which they must be familiar.

TRAINING AVIATORS FOR THE BRITISH ARMY

Few of us appreciate, when we read of the daring exploits of an aviator on the battle front in France, just what he does from day to day and just what he has to know. Nor have we even a faint idea of the training which a military aviator must undergo in these days. The schooling which an aviator must to through today is different from what was required of him only a few years ago, so rapid have been the developments on the western front. Only 3 years ago the military aviator was a mere theory; there was no definite conception as to his duties except that he was to fly and see what he could of the enemy lines, with an occasional bomb-dropping mission. Today, however, his whole status has changed, and he is perhaps the most versatile personage in the whole army.

We are apt to think of the aviator as a sort of special chauffeur, such as we might find at the wheel of a fast racing car—a man skilled in driving and with nerve enough to take chances with death in order to win the race. But such a driver is an amateur in comparison with the military aviator, for the mere piloting of the airplane is but a minor part of the duties of the military pilot. The modern aviator must not only be skilled in guiding his machine—and this includes all the tricks of looping, falling and other maneuvers to get away from or to mislead the enemy—but he must be an expert with the machine gun, must understand wireless telegraphy, must operate special cameras for observations and map making, must be a navigator insofar as it comes to flying by compass and following routes laid out from place to place, must learn to depend on the compass, to judge distances of cannon range and correct the gunners when their range is inaccurate.

In addition to all this the modern flier must become familiar with the theories of aviation, learn to know engines and their troubles, and last, but not least, be thoroughly familiar with military discipline in all its details. For when the success of a whole engagement may depend upon all the various units coöperating accurately and exactly, it is out of the question to have the aviator or any other important factor get to his post 5 or 10 minutes late because he did not appreciate the necessity of obeying orders exactly and to the minute. And this is all the more striking when we consider that the ages of the best aviators vary from 18 to 25, ages which do not usually respond to demands for hard and fast discipline in any line.

HOW AVIATORS ARE TRAINED

Candidates for the aviation corps come from civilian life at the ages already mentioned, and if they pass the medical tests are assigned to the cadet wing. The exact qualifications are extremely hard to define and depend more on how the young man "sizes up" after a little observation than on any set rules which can be laid down. Many college men make excellent fliers, but not so much on account of being college men as because they are alert, have receptive minds and are live wires generally. Their studies in Greek and mathematics have not much to do with it, as very little of the latter is necessary. In fact, many bright boys with only an elementary education make excellent military aviators. About the only calculations needed are to correct drift due to the wind, and with a good drift indicator even this is hardly necessary.

The main requirements for a military aviator are intelligence and courage rather than any specified knowledge as to mathematics, mechanics or other branches of the higher education. The more of these he possesses the better, but they are not essential to the making of a good military pilot, as has been demonstrated in many instances. It is because the college man usually possesses the first two requirements that he makes a good pilot, while his other accomplishments help him in the fine points of his various duties at the front. An ordinary education, including the three R's, makes a sufficient foundation if the first two requirements are in his mental make-up.

As all military pilots are classed as officers, beginning with a commission as second lieutenants when they get into actual military flying, it is found expedient to give them 2 or 3 weeks' military training in the early stages of their instruction. This makes them familiar with military drill in its various phases and fits them to take charge of small bodies of men in the flying camps, as well as to command other pilots as they show aptitude in their work and are advanced to first lieutenant, where they are in charge of a "flight," or part of a squadron, usually a third, or six, machines. Then comes squadron commander, wing commander, etc.

THE PRIMARY TRAINING

The preliminary, or primary, training includes, in addition to the military drill, a foundation of elementary theory of flight, of plane and engine construction, of wireless, photography, map making, gunfire control and the many activities which go to make up the duties of the military pilot at the front. This involves the use of actual engines, sometimes more or less in section, to show their construction and to become more or less familiar with their theory and method of operation, as well as the parts which are liable to give trouble and the way to remedy such difficulties. In the same way the general construction of the planes and other parts of the machine is pointed out, not with a view

2 **TRANSFER CARD** 7

NAME ....

RANK ....

REGIMENT ....

If passed, "Yes," with signature, or leave blank.

AERIAL GUNNERY.

School of Military Aeronautics ....

Elementary Training Wing ....

Higher Training Wing ....

School of Aerial Gunnery ....

WIRELESS.

School of Military Aeronautics ....

Elementary Training Wing ....

Higher Training Wing ....

PHOTOGRAPHY.

School of Military Aeronautics ....

CADETS.

Cadet Wing ....

School of Military Aeronautics ....

HIGHER TRAINING

	If passed "yes" or leave blank	Signature of Officer Commanding
Artillery Observation		
Bomb Dropping		
Camera Obscura		
Photography		
Fighting (practice)		
Formation Flying		
Cross-country-Flying		

Date of Graduation ....

Date of Appointment, R.F.C. ....

Types Flown ....

....

....

SOLO

DATE	HOURS	DATE	HOURS	DATE	HOURS	DATE	HOURS

FIG. 172.

of making the pilot an expert mechanic, but to give him a general knowledge, both for his own information and for its effect on the mechanics who will look after the machines for him. If the mechanics know that the pilot has a fair general knowledge of his machine, they are apt to respect his mechanical as well as his flying ability and look after his machine more closely.

Here also the aviator learns about stripping a motor and a plane, and the care of guns, the handling of wireless instruments, the artillery code, the artillery picture target, Panneau signaling and photography, with especial reference to cameras for aërial service. This instruction consists largely of lectures which are illustrated and explained in various ways, and on which examinations must be passed before the student can be passed to

6

CURRICULUM

SCHOOL OF MILITARY AERONAUTICS

	Qualifications	Signature of Officer Commanding
PRACTICAL.		
Stationary Engines. (Carburettor and Mag.).		
Rotary Engines.		
Instruments.		
Sail-making and Splicing.		
Rigging.		
Machine Gun.		
Miniature Range.		
Tools.		
LECTURES.		
Artillery Observation.		
Aerial Fighting.		
Bombs and Bombing.		
Cross Country and General Flying.		
Internal Combustion Engines.		
Map-reading and Reconnaissance.		
Meteorology and Astronomy.		
Mess Etiquette.		
Photography.		
Wireless.		
Types of Machines.		
Under-carriages.		
Signalling.		
Theory of Flight.		

HOURS FLOWN

DATE	HOURS	DATE	HOURS	DATE	HOURS	DATE	HOURS

3

AERIAL GUNNERY

SCHOOL OF MILITARY AERONAUTICS.
(a) Mechanism.
(b) Stripping.
(c) Drill.
(d) Care of Guns.

ELEMENTARY TRAINING WING.
(a) Standard Tests.
Nos. 1, 2, 3, and 5 (Lewis) and A. B. and C (Vickers).
(b) Immediate Action.
(c) Stoppages.
(d) Preliminary Firing Range, 25 yards.

HIGHER TRAINING WING.
(a) Instruction in Synchronized Gears for Vickers Guns.
(b) Ground Firing Practice.
(a) Test Nos. 4, 6 and 7 (Lewis), D, E, and F, (Vickers).

SCHOOL OF AERIAL GUNNERY.
(a) Firing from the air on the ground with Lewis and Vickers guns.
(b) Camera Gun Practice.
(c) Camera Gun Fighting between two Machines.
(d) Lectures on Aerial Gunnery.

RECORD OF PROGRESS

WIRELESS TRAINING AT SCHOOL OF MILITARY AERONAUTICS.

Subjects.	Requirements.
(1) Buzzing.	Six words per minute sending and receiving. Test of 3 minutes' duration.
(2) Artillery Code.	Written examination of 6 questions passed 80 per cent. correct.
(3) Artillery Picture Target.	Ranging 3 targets correctly, sending their map co-ordinates, and using Artillery Code and Ground Signals without error.
(4) Panneau Signalling.	Reading miniature Panneau accurately from distance of 100 yards, at a rate of 4 words per minute.

FIG. 173.

the first, or elementary, flying squadron. His record of progress is shown in the accompanying pages of the transfer card, Figs. 172 to 175.

But there is more to the examinations than the written tests. The whole character of the student is constantly under observation, and only those with the necessary qualifications, quite aside from book knowledge and mechanical ability, can be passed into the next grade which goes to the first training camp for actual flying. For unless the student has the necessary qualifications to do good work at the front, or at least to make an instructor, there is no use in taking up valuable time and smashing machines in the effort to get him into the air. It is what he does after he becomes a flier that counts.

4

Subjects.	Requirements.
(5) Sending on Silenced Key.	Clearly readable Tape Record produced at rate of 6 words per minute.

RECORD OF PROGRESS

WIRELESS TRAINING AT ELEMENTARY SQUADRONS.

Subjects.	Requirements.
(1) Buzzing.	Eight words per minute sending and receiving. Test of 3 minutes' duration.
(2) Artillery Code.	Written examination of 8 questions passed 80 per cent. correct.
(3) Artillery Picture Target.	Ranging 3 targets correctly, sending their map co-ordinates, and using Artillery Code and Ground Signals without error.
(4) Panneau Signalling.	Reading miniature Panneau accurately from distance of 100 yards, at rate of 4 words per minute.
(5) Sending on Silenced Key.	Clearly readable Tape Record produced at rate of 3 words per minute.
(6) Use of Wireless on Aeroplane.	Written examination of 6 questions passed 80 per cent. correct.

RECORD OF PROGRESS

WIRELESS TRAINING AT HIGHER TRAINING SQUADRONS DETAILED FOR INSTRUCTIONAL SUBJECTS,

a, b, c; A, B, C, D, E, (Letter A.O. 255 (A.O. 1).).

Subjects.	Requirements.
(1) Buzzing.	Eight code words per minute (counted 5 letters to a word), sending and receiving. Test to be of 3 minutes' duration.

5

Subject.	Requirements.
(2) Artillery Code and Contact Patrol.	Written examination of 10 questions, passed 80 per cent. correct.
(3) Artillery Picture Target.	To range 3 targets correctly, sending their map co-ordinates, and using Artillery Code and Miniature Ground Signals without error.
(4) Panneau Signalling.	Reading Panneau accurately from the air, at rate of 4 words per minute.
(5) Sending on Silenced Key.	Clearly readable Tape Record produced at rate of 8 words per minute.
(6) Artillery Puff Target.	One series of 10 puffs to be ranged correctly, map co-ordinates of target to be sent, and Artillery Code and Ground Signals correctly used.
(7) Ground Signals.	To send from the air correctly the meaning of 10 out of 12 Artillery Code Signals placed on the ground.

PHOTOGRAPHY

SCHOOL OF MILITARY AERONAUTICS

(a) Lectures on Photography.

(b) Lectures on Cameras used for Aerial Photography.

(c) Lectures on Photographing on Active Service.

FIG. 174.

Their training includes military drill and the school of aëronautics with its theory of aviation, the study of engines and planes and their construction, machine guns, instruments of aviation, wireless, map reading, location from the starts, etc. This preliminary training may take 1 month or 2, according to the pupil. When, in the opinion of the commanding officer, the student is qualified to proceed, he is assigned to the primary flying school for a course which usually takes about 2 weeks.

In addition to mere theory of flying the student is taken up with the instructor in a two-seated machine having double controls, and receives from 3 to 6 hours in the air with the instructor. This takes the place of the former method of "grass cutting," or "taxying," where the student drove a low-powered and clipped-wing machine around the field to learn the controls

8

TO PILOT

AT HOME

(1) Do not lose this card or your graduation will be delayed.

(2) On being transferred from one Unit to another, show this card to the Officer Commanding the Unit you are leaving, who will fill in what you have passed, and will leave the others blank

On arrival at your new Unit, show it again to the Officer Commanding your new Unit, and ask him to fill it in before you leave. If you fail to do this, or lose it, you are liable to be sent back to pass again.

ABROAD

On being posted to a Unit with the E.F., show the card to your Commanding Officer there. He will dispose of it as he thinks fit.

Fig. 175.

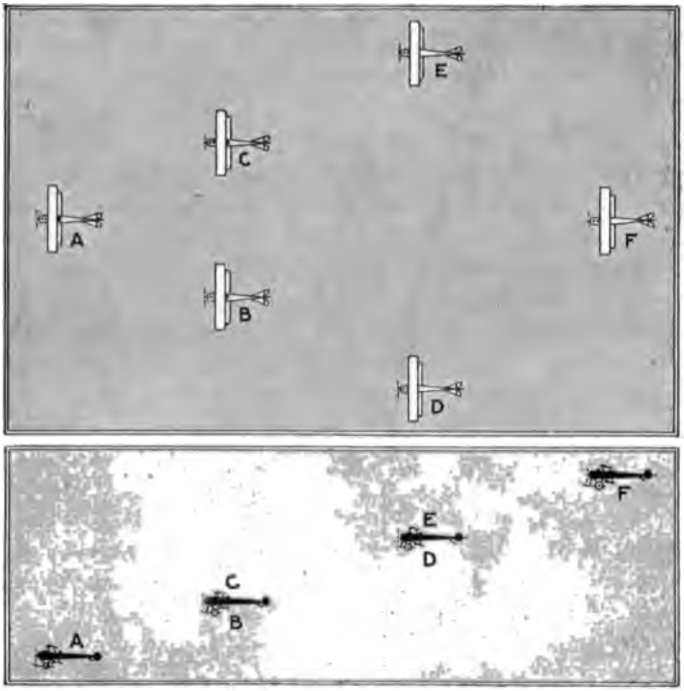
and gain confidence. The student gradually controls the machine more and more until the instructor finally relinquishes the controls and the student drives in the air and makes the landings, with the instructor always at hand to take the control of the machine should it become necessary.

When the student becomes competent to start and land a machine he is made to fly alone, or "solo," for from 5 to 7 hours and is then, at the discretion of the commanding officer, transferred to one of the advanced flying camps, where he generally spends about 6 weeks.

At this advanced camp his flying is divided into three parts, the first 2 weeks with the cross-country squadron, the second with the wireless squadron and the last 2 weeks with the gunnery squadron. The cross-country work covers quite a wide area of country and considerable high flying and has three tests which must be passed before going into the wireless squadron. The cross-country test is to fly a 60-mile triangular course, landing at two checking points and returning to the home camp. Then there are two height tests, one of 3000 and the other of 8000 feet, with four figure 8's to insure good control in turning in both directions, flying at the high points for at least 15 minutes to give confidence at these heights and finally to volplane, or glide, to earth with the engine shut off and land reasonably near a circle 50 yards in diameter, which is clearly marked by a border of broken stone.

There are also flights in flight or squadron formation, a typical formation being shown in Fig. 176–177. The officer in charge of the flight leads at *A*, the next two, *B* and *C*, fly a given distance behind, to one side and above the leader, the next two, *D* and *E*, following in similar order. The last man *E*, to guard against rear attacks, flys in the center and still higher, to be able to swoop down on an attacking plane at any time. The main difficulty encountered in formation flying is to maintain the exact relative positions, due to the difference in the speed of the various machines.

Having passed these tests, the student goes to the wireless squadron for another 2 weeks, where he is instructed in artillery observation, in bomb dropping, and in what is called "contact patrol," which means that he must make his observations at a height of only 500 or 600 feet from the earth. The artillery observation instruction has been very carefully worked out to reproduce actual war conditions in the simplest and most satisfactory manner. It includes the use of his wireless apparatus in signaling the batteries and the use of smoke puffs to represent the shots fired.



FIGS. 176 and 177.

TARGETS ON THE GROUND

With the machine gun mounted on the airplane, shooting at silhouette targets on the ground is part of the course, the machine being flown low for that purpose. In this work the machine gun is usually operated by a second man, as in a reconnaissance or raiding machine. In most of the air fighting, however, the machine is a single-seater, and the pilot operates the gun as well as the machine. In these cases the gun is usually fastened to the machine at the side, and is aimed by pointing the whole machine at the target, which is generally another machine. It is possible for an expert pilot to handle a movable gun in some cases, as he gives very little attention to his machine except in trick work, either attacking or eluding his enemy.

Another form of gun practice is at a target which is towed by another machine, but at a considerable distance behind it, much as is done in some forms of naval-target practice. This target is a piece of white cloth, perhaps 8 feet square, held at the front by a stick which is weighted to keep it vertical and towed far behind an airplane. This represents an enemy plane fairly well and is attacked by other planes carrying machine guns, these machines being designated by black triangular flags flown from the rear outer wing struts, to warn other machines to keep out of range of gunfire when they are in action.

THE CAMERA GUN

For machine-gun practice at enemy airplanes, the camera gun is also used, this being almost a duplicate of the Lewis machine gun and fitting in the same mounting. The film passes behind a glass screen ruled with small black circles for locating the position of the picture with relation to the bore of the machine gun, and these circles show on the photograph itself whenever an exposure is made. The camera is aimed by means of very ingenious sights, the same as on the gun itself, and the location of the enemy airplane on the circles shows exactly where the machine or the pilot would have been hit had an actual shot been fired. This makes an indisputable record, and the photograph forms a part of the students' record in this squadron (see Fig. 178.)

Having passed this section of the school, the cadet is assigned, at the discretion of the commanding officer, to go overseas for the final training on battle and scout machines before being sent to the front to win his spurs in action over the battle lines. The transfer card shows his studies and the record of them.

We must not forget that the aviator is not merely the pilot who enables someone else to make the necessary observation or to fight off the enemy planes when this becomes necessary, but that in nearly all cases he is absolutely alone, thousands of feet in the air, and that he alone must guide his machine, operate his machine gun, send his wireless message, make his maps or take photo-

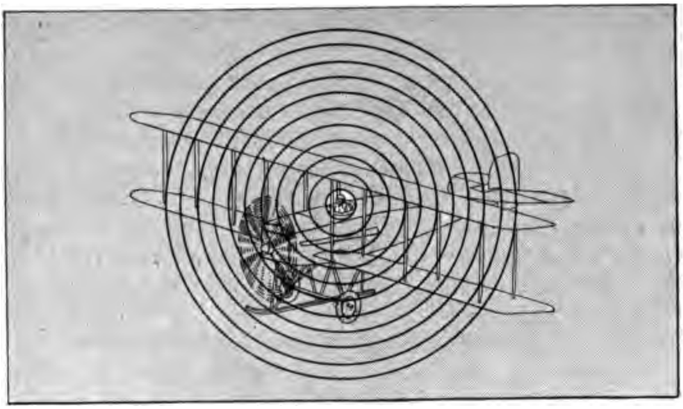


FIG. 178.

graphs, and that in most cases he is little more than a boy in years, yet with far greater responsibility and skill than most older men shoulder or acquire. The airplane is in its infancy, and it is to youth that we must look for its successful operation, for the present at least. It is to the intrepid daring of youth that we owe its development in the present war.

There are few serious accidents, but every provision is made for taking care of such as do occur. The ambulance, "hungry Lizzie," as the cadets call it, is always in readiness for an emergency call.

Suggestions for the Student in Aviation

These suggestions are by Roger Jannus, the well-known instructor, and while written some time ago, are still applicable in most cases.

The first thing for the student in aviation to learn and the last thing for him to forget is that aviation is a serious business. There is a strong tendency for familiarity to breed contempt in this, as in any other hazardous occupation, and we must be constantly on our guard against this state of mind. Flying looks so easy that almost every student is well provided with delusions and confidently expects that the few difficult points will, on account of his exceptional ability, be mastered in little or no time. Fortunately, only a few minutes in the air are required to take this out of him and make him perfectly tractable. The student must put himself absolutely in the hands of the instructor, and make up his mind at the start to obey orders to the best of his ability. He must constantly impress upon himself the necessity of keeping cool in a pinch, such as a forced landing. There have been rare instances of the student clutching the control and taking it away from the instructor, with disastrous results. But this will never occur if the student has the proper point of view and is on his guard against such an emergency.

The capable airplane pilot keeps a multitude of things in mind with very little effort. But the student should not concern himself with too many things at the same time. If his attention is not concentrated on anything in particular and he depends upon a hazy process of absorption it will take him much longer to become proficient. To illustrate, on his first trip or two he should devote his entire attention to the "elevator," learning to keep the machine at a given angle indicated by the instructor. As soon as a little proficiency has been acquired with this control, he will begin to use the aileron control, either stick or wheel, and so on, until he can keep the machine flying nicely in a straight line. This training will require about six trips.

Correcting Propeller Torque

By this time the student will have noticed that one wing has a tendency to stay lower than the other. This is caused by the torque or turning tendency of the motor. When the machine is turning a right-hand propeller, it will be the left wing which has the tendency to dip, but only a very slight pressure on the wheel will be sufficient to correct this, and keep the wings level. This torque effect is in accordance with Newton's law of motion, which states that when any force is in operation, there must always be an equal force acting in the opposite direction. Hence, when the motor turns the propeller to the right, it exerts an equal tendency to turn itself to the left. Going a little further, this force is the side action of the pistons upon the cylinders. In every explosion of a right-hand motor a strong pressure is exerted upon the left side of the piston. The sum total of these forces to the left is equal to the force exerted in turning the propeller, and they comprise the torque of the motor. This must be counteracted by the ailerons, unless some other provision is made for it. When the machine is gliding with reduced throttle, this force disappears and the wings stay level of their own accord.

It will also be noted that the Curtiss JN4 machine has a tendency to steer to the left when flying under power. This is caused mostly by the draught of the propeller. When the propeller passes through the air it pushes the air behind it and also gives it a whirling motion. In this and many other machines the rudder is slightly above the line of the propeller shaft, which puts it in the upper part of the draught. The whirling motion of this draught causes it to pass across the tail of the machine from left to right. It is the pressure of this air on the left side of the rudder which makes the machine tend to turn toward the left. The left aileron being carried slightly lower than the right to compensate for the torque also causes a tendency for the machine to turn to the left, but this is not as strong as the effect from the draught.

Making Turns

During the course of these first half dozen lessons the student will get somewhat familiar with the feeling of the machine while making a turn. Now he will begin making turns and circles himself. It takes more speed and more power to fly a machine in a circle than to fly it straight, and the smaller the circle, the more speed required to keep the machine from losing altitude. In the early days of flying when it took all the power available to keep the machine flying straight, it was necessary to allow for a considerable loss of altitude when making a turn, and the operation was more or less hazardous. Now when we have a good amount of reserve power things are quite different, and any good machine will be able to maintain its altitude on a circle unless it be one of very small radius. On large turns it is quite safe to permit the machine to climb, but for the student, practising turns of moderate radius, it is best to keep the machine flying horizontal, that is, neither descending nor climbing.

Supposing, now, we wish to make a left-hand turn, with a Curtiss JN4 tractor, going at about 70 miles per hour, and describing a circle of about 100 yards radius. The proper amount of bank for this turn will be about 20 degrees from the horizontal. To make the turn the student will gradually move his rudder to the left, and at the same time start the bank with the ailerons. In this way the rate of turning and the bank will increase gradually, steadily, and in the same proportion. When the machine is turning at the desired rate, stop the movement of the rudder and only sue it further to keep the machine turning at the same rate. About this time it will probably be necessary to bring the aileron control back to about its neutral position to preserve the angle of the bank, as the machine banks of its own accord. Machines differ greatly in the amount the ailerons must be used on the turn, and the same machine will act differently under different wind conditions, so no fixed rules can be layed down.

The student need not be in the least alarmed if he has to use the ailerons twice as much one day in making his turns as he did the day before. In any case, start the bank with the ailerons and after the turn is in progress use them in whichever way is necessary to make the machine do what you want. On a left-hand turn the elevator will not have to be used much to keep the machine flying level. In coming out of the turn, level up with the ailerons and straighten out with the rudder gradually, operating the controls in unison, and making the action as smooth as possible. In making a turn to the right the same operations are performed in the opposite direction, except with the important difference that there will be a decided tendency for the machine to nose down. This is on account of the gyroscopic action of the propeller, and it will require a moderate use of the elevator to keep the machine level.

Gyroscopic Action of Propeller

This gyroscopic action of the propeller is sometimes quite strong and it is well to understand it thoroughly. Without a knowledge of this force its manifestations will seem mysterious and sometimes disconcerting. The action is as follows: In this case, the airplane propeller is the gyroscope, and the axis of rotation is the propeller shaft, or crankshaft. Now, when we turn this axis in any plane, the gyroscope causes resistance to the turning forces, and at the same time exerts a tendency to turn around an imaginary straight line in the same plane, but at right angles to the axis of rotation. The direction in which the gyroscope tends to turn around this imaginary line, normal to the axis, depends upon the direction of rotation of the gyroscope. In making a turn to the right with a right-hand propeller the gyroscope is turned in the horizontal plane. It tries to resist this motion, but it is not strong enough for that and the pilot is not even conscious of the resistance, because it is the same whether the turn be to the left or right. The line around which it has the tendency to turn, will lie also in the horizontal plane, and at right angles to the crankshaft of the motor, and the nose of the machine will tend to rotate downwards around this line. Hence the machine tends to dive on the right turn. On the left turn the machine tends to nose up, as the forces are just reversed. This same reasoning will hold good for any gyroscopic action.

Flying Level and Stalling

It is always difficult for the student to tell when he is flying level, when he is climbing at the maximum safe climbing angle, and when he is stalling. A machine is said to stall when it no longer has the power (or speed in the case of a volplane) to maintain its true line of flight, determined by the axis of the fuselage. If you try to make a machine climb at too great an angle, it will have to expend so much of its power in lifting the machine vertically that an angle is eventually reached at which the machine will be slowed down below its minimum flying speed. If held at this angle the machine will no longer climb at all but will begin to settle. This is a dangerous condition as the controls have very little effect and a bad puff may upset the machine. However, the condition need not be feared, as it is easily recognized by the limp feeling of the controls, a wobbly feeling in the whole machine, and a laboring of the motor. The student will be required to keep the machine level or at moderate angles as indicated by the instructor, and he will have to learn to recognize the correct angles by the appearance of some part of the machine, nose, struts, wing, etc.

After the student has made some turns and begins to handle his controls with a degree of confidence, he will begin to have an idea of the proper amount of bank required. The speed of the machine and the radius of the turn determine this angle. The greater the speed of the machine, the greater the angle of bank required for a circle of given radius. And if the speed of the machine be constant, the smaller the circle, the greater will be the bank required. When the machine is not correctly banked it will side-slip.

If the bank is too small the slipping will be outward. This is not dangerous. If the bank is too great, it will slip inward and downward. This is dangerous.

When the machine is slipping outward it is corrected either by banking more or making the turn larger. When slipping downward, give less bank or make the turn smaller. A pilot should be able to tell when he is banking properly by the feeling of his machine, but many never acquire this ability. A spirit level will tell the truth, and often the wind can be felt coming in sideways when the machine is slipping. Mention has been made above regarding machines settling on turns. This is quite different from side-slipping. A machine will never side-slip if properly banked, though it may settle badly. When the machine is banked, its wings may be considered as shortened to a span equal to the vertical projection of the wings on the horizontal plane. Obviously, if the effective surface is sufficiently reduced, a point will be reached when it is no longer capable of sustaining the machine, and settling will be the result. This settling is not dangerous, but must be anticipated when flying at low altitudes.

Rising and Landing

Practising turns will occupy the full attention of the student for about six lessons. Now twelve lessons, or about half of the instruction time has been exhausted. The remaining twelve lessons will be occupied in learning to take the machine off the ground and to land it. Landing a machine is the great bugbear of the students, and is doubly difficult because even slight mistakes are very noticeable, and the penalties may be severe. There are two recognized methods of landing, both of which are in common use, referred to as the slow, or tail-low landing; and the fast, or tail-high landing. The slow landing is the type which should be learned by the student, as it is the safest under all conditions and the only practical method for rough ground or coming into small fields. Suppose we are coming into the field on an easy glide. Begin to bring up the nose when the machine is about 30 feet from the ground and continue to draw in on the elevator very gently. This must be timed so that the machine becomes level when it gets about 4 feet above the ground.

By this time the machine has lost flying speed and is beginning to settle rapidly. At the same time the elevator is being brought back firmly, causing the tail to drop, and the machine to lose speed still more rapidly. The great angle of incidence of the wings keeps the machine from dropping too rapidly. It should alight on the wheels and tail skid at the same time. In this position it lands at the least possible speed and makes the shortest possible run, with the exception of a pancake. In case a forced landing is necessary in a field so rough or small that it is impossible to land without damaging the machine to some extent, the machine should be "pancaked." That is, carry out the same methods as above described, except do it a few feet further from the ground. The machine will settle heavily to the ground and the landing gear may be damaged but the speed will be further reduced, lessening the danger of running into some ditch or obstruction. Remember, never run head first into anything. In case of trouble this is absolutely the most important thing to remember. Switch off the motor to avoid the possibility of fire, and do anything rather than run into anything solid. If the machine is brought down tail first or on one wing the chances of serious injury are greatly lessened.

In making a tail-high landing the machine comes into the field slightly faster and is brought toward the ground in much the same manner, except instead of bringing the tail down low, the machine is permitted to glide about level until it settles and runs on the wheels only. In this case the tail is kept up, which keeps the machine from bouncing. Care must be taken not to let the tail drop until flying speed is entirely lost, as it is very easy to drop the tail too quickly, in which case the machine will glide up into the air again until its speed is gone, after which it will fall to the ground with a thud.

Getting off the Ground

In taking the machine off the ground, great caution is necessary. It must be kept straight from the start or trouble will follow. There are two factors which tend to turn the airplane to the left. First, in the case of a right-hand tractor like the JN, the torque of the motor presses down the left wing and wheel, causing a greater resistance on this side. Second, the rudder being above the line of the propeller gets more blast on the left on account of the whirling motion of the air stream, the same as in flight. These factors taken together become quite effective, and at the same time the tail skid is digging into the ground so that the tail does not readily respond to the rudder as it does when the tail is clear of the ground. Hence, the student must be on his guard against this tendency to turn. A good precaution is to start out with the rudder bar a little to the right and the wheel banked a little as if to put the machine into a right-hand bank. This will offset the turning tendencies. The student will also notice that as the machine picks up speed the rudder seems to become more and more alive under his feet, and the faster the machine goes the less motion is needed to produce the same amount of turning. When the machine is going slowly the rudder must be moved strongly to give any results at all.

Suggestions as to Air Conditions

There are in circulation a number of rules and notions as to the proper way to maneuver when puffs and bad air currents are encountered, but these are very likely to be misleading, as few people really know much about the inner workings of the atmosphere. There are some points, though, which are well enough understood to be dealt with here. One bit of advice always holds good and that is: "Do not fight the wind any more than you have to." Most pilots use the controls more than necessary. A well-designed machine will do a great deal for itself if you give it a chance.

A machine will frequently get a boost, that is, will rise rapidly for 2 or 3 seconds without any great change of angle. This may be caused by air that is actually travelling in an upward direction; or by air that is travelling at a different velocity from that out of which the machine has just passed, causing a momentarily greater velocity of the machine with respect to the air. The machine will also rise when passing into colder air. In any of these cases there is no cause for anxiety, and nothing out of the ordinary need be done.

Exactly the reverse case will cause the airplane to drop rapidly. This is rather an uncomfortable feeling at first, but one gets used to it and the machine is perfectly safe. There is no necessity for heading down, or anything like that. On this account, though, it is never safe to pass over any object with only a small margin of clearance, as one may be dropped directly on to something. When an airplane passes into the hot smoke of a chimney it will drop with great suddenness, although the column may be rising rapidly. Then it is no longer in air, but is in a mixture of light gases of very poor supporting power. So do not try to take the lightning-rods off any chimneys.

It is very desirable that the pilot should have a clear understanding of relative velocities. The wind will have a certain velocity, relative to the earth, or course, which we must take into consideration when going from the earth into the air, or from the air onto the ground. But when we are clear of the ground and depending entirely upon the air, its velocity over the earth does not affect the flying of the machine at all, except as to the navigation of the machine from one point to another. In other words, we may make circles in the air, glides, dives, etc., just as if the air had no velocity at all. When the wind is blowing it is just as if the wind were still and the earth moving beneath it. Some people fancy that when they are flying into the wind and wish to lead around so the wind is behind them, that they must make a large turn and give themselves time to pick up velocity. They get this impression from the fact that when heading into the wind they are going slowly over the ground and when they turn around they will be going very rapidly with respect to the earth. This example is cited as a typical fallacy and has no foundation whatever on fact. In making such a turn your velocity relative to the wind does not change in the least, and your changes of velocity relative to the ground will be taken care of by the wind without any strategy on your part.

Changes of Velocity and Wind

The reason that these and similar ideas have gained such popularity is that the machine does actually handle differently with the wind on different quarters. In a wind of 20 miles per hour the real velocity will probably vary from 10 to 30 miles per hour and these changes will take place in a fraction of a second. There will be other velocity changes taking longer periods of time, and so on. A strong wind will have a countless number of little velocities, vortices, wave motions, and other characteristics. It is the action of these internal movements in the wind, affecting the machine from different angles that we notice.

As a general rule, the stronger the wind the more numerous and the stronger will these internal movements be; and the more we will notice the differences between flying into the wind and with the wind behind. The air will be found exceptionally bumpy when it is changing in direction; also when the velocity is increasing or decreasing rapidly. The smoothest wind is encountered when it has travelled a long distance over water. Obviously, wind from a city or mountainous country will be very irregular and will require considerable use of the controls.

It is generally stated that a machine will climb better headed into the wind. This is more often true than not, but there are times when the machine will climb better with the wind on the tail. Do not get the idea that you cannot climb unless headed into the wind or you will often go to unnecessary trouble. When flying within a few feet of the water with the wind on the tail in winds of 30 miles per hour or better, it will be very difficult and sometimes impossible to climb. This condition is caused by the rolling motion imparted to the air by its friction against the water. This rolling motion increases with the velocity of the wind and may be a source of great danger.

It is easily avoided, however, by keeping at least 50 feet, and preferably higher above the water when the wind is behind. When flying in a strong puffy wind, it is not well to keep the machine climbing at its maximum angle. In this position it has little reserve speed and if the climbing angle is suddenly increased by a puff, the machine will be in a bad position to combat a second or third puff if such should be encountered. The same reasoning holds good when making a sharp turn and a steep bank. The machine is more easily put into a dangerous position. These warnings are only of importance while still relatively near the ground, say within 1000 feet. After good altitude has been attained, and there is plenty of room to straighten out, many precautions may be neglected by the skillful pilot.

Not the least important feature of flight is strategy. You will be well repaid for looking ahead and avoiding complicated situations. It is much better to keep out of trouble than to be clever at getting out of it. When flying in bad country, study the local conditions and map out your flight in your mind so as to keep within reach of good landing grounds as much as possible. Look far ahead, and also behind.

SELECTING MECHANICS FOR THE ROYAL FLYING CORPS

Considerable discretion must be exercised in the selection of mechanics for the flying corps, as so much depends upon the mechanical condition of the airplane. Men who apply for enlistment in this department are questioned carefully by the officer in charge and are then tested as to their proficiency in their respective lines before being accepted for service. This is called "trade testing," and is accomplished by requiring the applicant to perform the various kinds of work in which he claims to be proficient.

Applicants who desire to be fitters or machinists are questioned regarding their knowledge of motors and of such machinery as they will be obliged to handle. Their ability to use the lathe and similar tools is ascertained by putting them at work on a lathe mounted in an auto-truck machine shop such as is actually used behind the lines on the western front. Here the men must satisfactorily show that they understand how to do the kind of work which will be required of them. If the applicants are not qualified as fitters, they are classed as helpers, with the possibility of being advanced later if they progress.

Carpenters or cabinet makers are tested in the making of dovetail and other joints, and if they pass this satisfactorily they will be employed to repair the various wooden parts of the airplane, such as the fuselage, wings, wing struts and landing gear. Sailmakers and those having training in the making of tents, overalls or other garments, are employed to cover planes and do similar work. For testing these, a small section or panel of a wing is utilized, the applicant being requested to sew up an L-shaped tear. The neatness with which this is done shows his experience.

In a similar way sheet-metal workers are tested by being required to cut, shape and solder several small sheet-metal pieces of various designs so as to show whether they are capable of repairing or replacing some of the sheet-metal parts of an airplane, such as engine hoods, gasoline tanks and radiators.

After the men have been selected, they are enlisted in the regular way and given a certain amount of military drill, principally for the sake of instilling in them an understanding of the necessity for discipline and a sense of responsibility regarding the quality of the work and the necessity of having it done promptly. They are instructed in the construction of internal-combustion motors in general and in the particular types in use in the camp at which they are to be stationed, and receive considerable information which will help them to perform their various duties.

When the men who are assigned to each "flight," which in this case means six machines, or a third of a squadron, are thoroughly trained, they become extremely proficient. Each man has a certain part of the work to handle in dismantling or disassembling a machine that may be in need of repairs for any reason. When a student makes a bad landing and crumples his running gear under the wings, it takes but a very few minutes for the repair crew to take the wings off the body, or fuselage, after which the machine is taken to the hangar for repairs. Each man is responsible for a certain portion of the work, and all connections are quickly taken out so that the various parts may be separated easily.

The form shown is for recording the number of men enlisted in the various branches, and gives some idea of the variety of mechanics required.

The men march to and from their quarters in military formation and are under military discipline.

SPARE PARTS FOR TRAINING AIRPLANES

The problem of keeping airplanes in service requires constant care and a corps of trained mechanics to make necessary changes and repairs. But more than this, it also necessitates having a goodly supply of spare parts to draw from, so that damaged wings, ailerons, landing gears and other parts of the machine itself, not to mention small parts of the engine, may be readily replaced and the whole machine put back into service at the earliest possible moment. In this connection it is extremely interesting to note the experience of the Canadian Division of the Royal Flying Corps, as its practice forms a very good basis upon which to estimate the number of spare parts it is necessary to keep on hand.

The enumeration is given merely as a suggestion, as the parts required vary widely from day to day; and if a new list were to be compiled a month from now, it would probably be changed in several particulars.

A study of the accompanying tables, however, particularly in regard to the parts of the planes themselves, shows several interesting features. For example, it has evidently been found that twice as many lower planes are damaged as upper planes, and this can readily be understood after one sees the wheels or struts of the landing gear forced back under and sometimes up through the fabric of the lower plane. Damage to the upper plane is much less likely to occur, and only half the number of spare parts is provided on this account.

Both the skids under the end of the wings, or canes, as they are called in this list, and the axles of the landing gear are evidently needed in quite large quantities. In the same way, wheels for the landing gear and inner tubes for the tires are required in large quantities, while the tires themselves are ordered in only comparatively small numbers. This indicates that tubes are very apt to be blown by having the tires forced sidewise over the rim, rather than by puncture, which would affect the tire itself as well as the tubes. Wheels are also frequently damaged by landing with considerable side motion, which crumples the rim and twists the spokes out of shape.

Only half of these spare parts are issued to the squadron in the beginning, the remainder being kept at flying headquarters, so as to have the latter act as a reservoir for supply. Then, in case any one flying camp has an epidemic of accidents of a certain kind, the extra spare parts needed can be drawn from the extra supply at the central depot stores. The list follows:

TABLE I.—ENGINE SPARES FOR 100 MACHINES

Description	Repair section at Borden	Aircraft depot	Engine-repair section
Auxiliary air-intake assembly	10	10	20
Breather pipe assembly	5	5	10
Cam follower guide assembly	30	100	100
Camshaft assembly	2	4	10
Camshaft gear	6	20	30
Camshaft bearing front	...	3	10
Camshaft center	...	9	30
Camshaft rear	...	3	10
Carbureter complete with braces and stubs	5	5	10
Carbureter setting jets, assorted	60	50	100
Carbureter setting choke, each of three sizes	3	3	10
Carbureter setting pilot jet No. 40	6	6	15
Carbureter setting compensator No. 100	6	6	15
Carbureter hot-air box assembly	10	10	20
Connecting-rod assembly complete with bearings	16	24	120
Connecting-rod bearings complete	16	24	120
Crank-case lower half assembly	2	5	10
Crank-case oil-drain plug	10	10	10
Crank-case upper half assembly	2	2	5
Crankshaft with plugs, gear, nuts, lock rings, complete	2	5	10
Crankshaft bearings, front main upper	...	5	10
Crankshaft bearings, center main upper	...	15	30
Crankshaft bearings, rear main upper	...	5	10
Crankshaft bearings, caps front upper	...	10	20
Crankshaft bearings, caps center upper	...	30	60
Crankshaft bearings, caps rear upper	...	10	20
Yoke cylinder tie down	30	60	200
Water-pump stud shaft	2	5	10
Crankshaft gear	2	5	10
Crankshaft lock wire	30	50	50
Cylinder assembly with jackets only	40	100	100
Exhaust-valve spring seat washers	100	200	500
Exhaust valves	50	150	300
Exhaust-valve springs	200	250	500

TABLE I.—ENGINE SPARES FOR 100 MACHINES—(*Continued*)

Description	Repair section at Borden	Aircraft depot	Engine-repair section
Inlet valves	20	100	200
Inlet-valve springs	200	250	500
Cylinder gaskets	50	150	500
Engine-bed bolt assembly	60	120	240
Front gear-case cover assembly	2	5	10
Front gear-case cover packing nut	10	20	50
Intake manifold pipe and Y-assembly	5	10	15
Magneto drive assembly complete	2	5	10
Oil-pump release-valve assembly	2	10	20
Oil-pressure regulator-valve spring	20	50	100
Piston complete with rings	20	50	100
Piston rings	300	500	500
Piston pins	20	50	100
Propeller-hub back wire	100	100	10
Rocker-arm and push-rod assembly	50	50	100
Rocker-arm bearing pin	50	50	100
Intake push-rod and bearing pin	50	50	100
Exhaust push-rod and bearing pin	50	50	100
Bushings reducer, 3/8 to 1/4 inch	10	20	50
Tachometer with flexible shaft	10	15	20
Tachometer drive shaft	20	25	30
Tachometer drive gear	20	25	30
Tachometer driven gear	20	25	30
Thrust bearing with adapter ring	2	5	10
Thrust-bearing adapter ring	10	20	30
Thrust-bearing lock ring	10	20	30
Thrust-bearing lock-ring nut	10	20	30
Thrust-bearing end clamp	10	20	30
Oil sight-feed assembly	2	5	10
Water inlet-pipe assembly	4	10	20
Water outlet-pipe assembly	4	10	20
Water-pump assembly	2	5	10
Water-pump shaft	10	20	30
Water-pump impeller	10	20	30
Water-pump impeller locknut	10	20	30
Water-pump bushing, large	20	40	60

TABLE I.—ENGINE SPARES FOR 100 MACHINES—(*Continued*)

Description	Repair section at Borden	Aircraft depot	Engine-repair section
Water-pump bushing, small	20	40	60
Water-pump shaft collar	20	40	60
Water-pump shaft washer, large	20	40	60
Water-pump shaft washer, small	20	40	60
Water-pump shaft coupling	2	5	10
Water-pump shaft center	2	5	10
Water-pump shaft member	2	5	10
Water-pump stud shaft spring	10	20	30
Water-pump packing nut, small	10	20	30
Water-pump packing nut, large	10	20	30
Magneto high-tension cable, yard	50	50	50
Magneto leather cover	2	5	10
Oil pressure gage	2	5	10
Gasoline shut on cock spring lock	2	5	10
Camshaft gear puller	2	5	10
Crankshaft gear puller	2	5	10
Complete set of gaskets for motor	10	10	30
Valve lifter	2	5	10
Muffler exhaust	4	10	20
Elbows for exhaust muffler	20	50	100
Oil-pump assembly	2	5	10
Oil-pump gears, each	20	50	100
Oil-pump gears, shaft bushing	20	50	100
Crank-case cover assembly	2	5	10
Magneto coupling rubber segments	300	300	500
Magnetos and Sparks for Magnetos			
Magnetos complete	5	10	10
Interrupter contact springs	...	...	30
Interrupter contact screws	30	20	30
Interrupter cover assembly	...	...	5
Interrupter lever clamp spring	...	...	30
Interrupter contact lock screw	...	...	30
Interrupter lever	5	10	25
Interrupter cushion spring	...	...	30
Interrupter lever coil spring	...	...	30
Interrupter spring mounting screw	...	...	30

TABLE I.—ENGINE SPARES FOR 100 MACHINES—(*Continued*)

Magnetos and Sparks for Magnetos	Repair section at Borden	Aircraft depot	Engine-repair section
Interrupter block mounting screw insulating bushing	...	...	30
Interrupter block mounting screw insulating washer	...	...	30
Interrupter block mounting screw washer	...	...	30
Interrupter block mounting screw	...	...	30
Interrupter hexagon screw insulating bushing	...	...	30
Interrupter ground brush	30	20	50
Interrupter ground brush spring	30	20	50
Interrupter hexagon mounting screw	...	...	30
Interrupter adjusting wrench	3	6	10
Cam housing	...	...	5
Cam-housing clamp	...	...	5
Pinion	...	...	30
Pinion keys	...	...	50
Condenser assembled	...	...	5
Terminal plate assembled	...	...	30
Condenser mounting screw	...	...	5
Primary clamp lock screw	...	...	30
Norma ball bearing (driving and interrupter ends)	...	...	5
Interrupter end bearing	...	...	5
Driving end bearing	...	...	5
Dust washer	...	...	5
Dust-washer clamp	...	...	5
Distributor gear assembled	...	...	3
Distributor block	...	...	2
Distributor block cover	...	...	2
Cable terminal plug assembled	...	...	5
Distributor block stud, lower	...	...	60
Distributor block stud, upper	...	...	30
Distributor block clamping spring assembly	...	...	5
Distributor finger assembled	...	...	5
Distributor finger brush (square)	50	20	50
Distributor finger brush spring	30	20	50
Distributor finger contact brush	15	10	25

Table I.—Engine Spares for 100 Machines—(*Continued*)

Magnetos and Sparks for Magnetos	Repair section at Borden	Aircraft depot	Engine-repair section
Distributor finger contact brush spring	15	10	25
Collector brush	15	10	25
Collector brush spring	15	10	25
Spark gap yoke assembled	...	...	3
Spark gap yoke contact button	...	...	5
Spark gap yoke contact button spring	...	...	30
Spark gap yoke mounting screw	...	...	10
Brush-holder assembled	...	...	5
Brush-holder cover assembled	...	...	3
Brush-holder clamp assembled	...	...	3
High-tension terminal nut	15	10	25
High-tension terminal washer	15	10	25
Adjustable bearing bushing nut	...	...	5
Adjustable bearing bushing	...	...	5
Adjustable bearing bushing clamp ring	...	...	5
Adjustable bearing bushing clamp ring screw	...	...	5
Adjustable bearing ball bearing	...	...	3
Adjustable bearing spacing ring	...	...	5
Terminal plug clamp assembled	...	...	5
Terminal plug clamp bracket assembled	...	...	5
Terminal plug clamp bracket screw	...	...	10
Gearshaft nut lock screw	...	...	10
Bearing screw	...	...	10
Magnet straps	...	...	3
Magnet straps screw	...	...	30
Shaft washer	...	...	30
Shaft nut	...	...	30
Gearshaft washer	...	...	30
Gearshaft nut	...	...	30

Table II.—Airplane Spares for 100 Machines

Article	Quantity
Ailerons, top right-hand, complete with fittings	40
Ailerons, top left-hand, complete with fittings	40
Ailerons, bottom right-hand, complete with fittings	40
Ailerons, bottom left-hand, complete with fittings	40
Axles, metal, with caps and flanges	100

TABLE II.—AIRPLANE SPARES FOR 100 MACHINES—(*Continued*)

Article	Quantity
Bearers, engine, complete with fittings, pairs	20
Brackets, fuselage, for struts, sets	75
Brackets, wing skids, sets	25
Bridges, connecting, struts	50
Canes, wing skid	200
Controls (dual), sets	5
Cord, elastic, shock absorber, yards	600
Covers, canvas, outer, for wheels	10
Covers, canvas, inner, for wheels	10
Cowling, engine	5
Cowling, undershield	5
Elevators, pairs	15
Fairings, axle, complete	100
Fins	20
Masts, wing, sets	40
Planes, main top, right-hand, complete with fittings	35
Planes, main top, left-hand, complete with fittings	35
Planes, main bottom, right-hand, complete with fittings	70
Planes, main bottom, left-hand, complete with fittings	70
Planes, tail, complete with fittings	10
Planes, center, complete with fittings	20
Propellers	200
Radiators	20
Rudders	60
Skids, tail, complete	20
Struts, main plane, outer, front	50
Struts, main plane, outer, rear	50
Struts, main plane, intermediate, front	50
Struts, main plane, intermediate, rear	50
Struts, central front	25
Struts, central rear	25
Struts, inter aileron	20
Struts, right-hand, front	100
Struts, right-hand, rear	100
Struts, left-hand, front	100
Struts, left-hand, rear	100
Tanks, main petrol	5
Tubes, inner	250
Tires, outer	25
Wheels, complete	250
Windscreens	10

AIRPLANE ENGINE REPAIRS AT TORONTO

The Canadian Division of the Royal Flying Corps is systematically arranging for the repair of airplanes and engines. With headquarters in Toronto, the division is planning to have general repairs to both engines and planes made at that point. All the flying fields, which include the first, or primary, field at Deseronto and the secondary fields at Leaside, Ridley Park and Camp Borden, have what might be called field repair shops for minor repairs and also for the regular overhauling and cleaning which become necessary after 50 hours of actual flying. In the same way minor repairs to planes and landing gear are also made in the shops at the various flying fields.

When, however, a crankshaft has been bent by a severe crashing of the machine on landing, no repairs are attempted at the flying field, but the complete engine is shipped to the main repair shop at Toronto. Here it is taken apart and thoroughly examined in every particular. Broken and damaged parts are removed and replaced, and the engine put in shape for actual service and shipped back to the flying field as soon as it has been tested.

Owing to the difficulty of securing skilled mechanics for all this work, it has been found advisable to pick the best men available and train them along special lines of repairs. Under the guidance of a few skilled mechanics men become fairly expert in handling connecting rods, piston pins and work of that kind, and this method has been found to work out as well as can be expected where skilled men cannot be secured. It takes comparatively little training to make a man fairly skillful, and by keeping him continually on some particular job he soon learns to handle it in a very satisfactory manner.

BOXES FOR EASY HANDLING

Special trays, or boxes, which can be easily handled, are made for holding the different parts on their way through the shop, and great care is taken to have every part absolutely right before the engine is reassembled. The forms used in keeping track of this work as it goes through the shop are illustrated herewith.

Engines are allotted to Engine Repair Park, as the shops are termed, by the Royal Flying Corps headquarters. Each engine is given a logbook for all future work. This book gives a complete history of the engine at all times. On receipt of allotments, a job number is given to the engine by the commanding officer, and all departments are advised of this number when they receive the engine.

The engines are then sent to the dismantling department, which immediately advises the office of the commander that they have been received, giving both their own and the maker's number. The logbooks then go to the office, which forwards them to the inspection department; there particulars of all work required to be done are filled in, and the work actually performed and passed is entered. No department except the inspection department makes entries in the logbooks.

On completion of the engine, the logbooks are returned to the commanding officer for his signature. These books are packed and dispatched with the engines to the flying fields. The entries in the logbooks, while as concise as possible and not giving details as to the replacement of bolts, nuts, etc., only the main parts being mentioned, are such, however, as to enable the squadrons to obtain a good knowledge of the work which has been done on the engines.

Should it be apparent from the condition of the engine that it has not had fair treatment while with the squadrons, an entry to that effect is made in the logbook and where possible a remedy is suggested. No work is started on an engine until after receipt of the job number.

THE FORMS USED

The dismantling department makes out Form No. 1, Fig. 179, in duplicate, retaining one copy and forwarding the other to the inspection room. All parts of the engine are thoroughly cleaned before leaving the dismantling department and the valves lightly ground in to facilitate inspection.

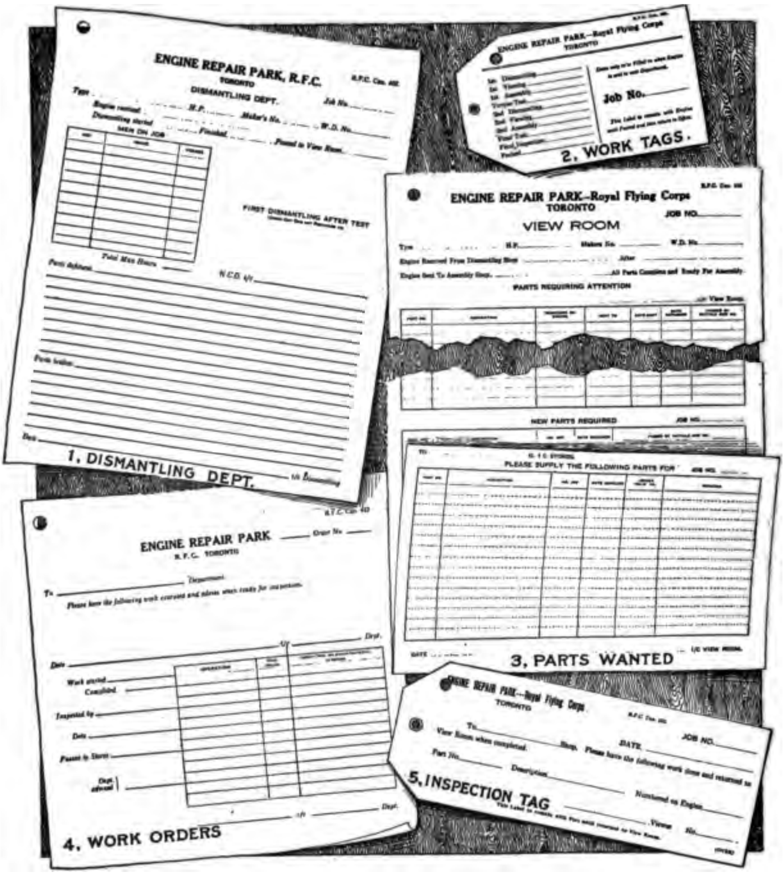


FIG. 179.

The dismantling department also makes out a blue tag, Form No. 2, furnishing as many copies as there are parts trays for the engine. These forms remain with the engine until it has passed through the shops and is ready for packing.

Form No. 3 is made out by the inspection department, the lower portion being used for drawing parts from the stores. This leaves a carbon copy of stores drawn for the sheet beneath. The carbon copy is retained and completed by the inspection room upon receipt of parts.

Form No. 4 is made out by the inspection department. It gives particulars of the work to be done and is attached to each part requiring attention. The department doing the work completes the form, sending it back to the inspection room together with the part when the work is finished. No engine leaves the inspection room until it is complete in all its parts. Should any parts not be in stock, the engine remains there until they are secured and have passed inspection. A red tag, Form No. 5, remains with the engine until its return to the inspection room.

Form No. 6, Fig. 180, is now started by the inspection department, and this, together with its envelope, No. 7, remains with the engine until it is completed. All entries on this card are made by the inspection department, which forwards it to the commanding officer as soon as the final test of the engine is completed and it is ready for service.

Form No. 8 is made out by the assembly department, the inspectors signing in the top right-hand column as the several operations of assembly are inspected and passed. A carbon copy of the valve and magneto setting is made and forwarded direct to the testing department.

Form No. 9 is then made out by the test department. The setting of the valves and the magneto is shown as it remains after the engine has been tested and passed for torque. This will not necessarily be the same as that given by the assembly department if better results can be obtained with some other setting. All settings are given in degrees and not as measurements of the stroke.

On completion of the tests, Form No. 9 is sent to the office c the commanding officer, where it is duplicated on Form No. 1 for sending out with the engine logbook. The original is the

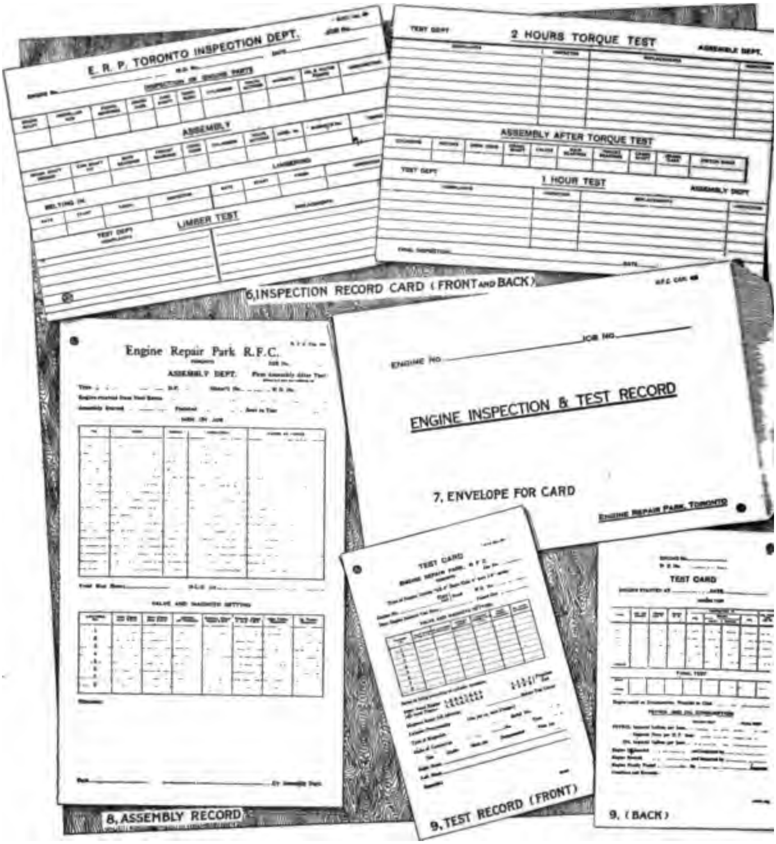


FIG. 180.

returned to the test department, where it is filed for futur reference.

As the engine passes through the shops for the second dis mantling, reassembly, etc., after the first test, a second form, having the same job number as the original, is made out by each department. These forms are kept with the first forms by each department. Each department keeps its completed forms in numerical order, according to the job numbers, so as to be easily found for reference. All departments make a daily report before 9 a.m., as shown in Form No. 11, to the commanding officer in charge of the entire school.

Form No. 12 shows an engine-record card which is kept in the office of the commanding officer and is brought up to date from the returns by the several departments given in Form No. 11. This gives a concise history of each engine as long as it remains in service.

All time spent and material used at the repair park are accounted for under the headings which show where all charges should be made.

Job numbers include all time and material used in connection with the repair and rebuilding of airplane engines and also the overhaul and repairs of motor transport vehicles. These numbers are allotted by the commanding officer, who advises the departments concerned of the numbers allotted to each engine or motor transport vehicle.

Stock numbers include all time and material used on manufactured work, such as engine parts, tools or articles manufactured for other units. All requests for this class of work are made out on a special form, the article passing through the inspection department. They are then transferred to the repair stores and reissued by them to the proper department.

All order numbers originate in the drawing office, where a book is kept which records all numbers issued. Where drawings are required, these bear the stock order number in addition to its drawing number. Should further similar articles be required after completion of the first order, the new order will have the same number as the original and be followed by a letter of the alphabet, commencing with A.

HOW ORDER NUMBERS ARE GIVEN

Works order numbers include all repairs or alterations to machine tools, plant or buildings. Requests for this class of work are made out by the department requiring the work to be done. This takes a works order number preceded by the initial letters of the department, for example, W. O. M/S202 stands for works order number 202, issued by the machine shop. Each department keeps a record of all orders issued.

Permanent works orders (common to all departments). Only time spent on these orders during the working hours of the park is to be accounted for.

Working order number 1001—Cleaning.

Working order number 1002—Drill.

Working order number 1003—Guards.

Working order number 1004—Leave.

Working order number 1005—Excused duty or hospital.

Working order number 1006—Orderly duties.

Working order number 1007—General work in connection with laying out plant.

Each department renders a weekly summary of all time, in man-hours, worked on each order. This goes to the stores by 9 a.m. Monday. The stores keep a record of all time spent and material used on each order, in the form of a loose-leaf ledger.

Time sheets are made out by all noncommissioned officers below the rank of sergeant (with the exception of clerks and storemen).

The time sheets are signed by the noncommissioned officer in charge of the section, and passed to the officer in charge of the department, who files them when the necessary information has been secured.

PARTS THAT NEED ATTENTION

After an engine has been run from 100 to 150 hours, it is given complete overhauling. New connecting-rod bearings, and in most cases main bearings, are also installed. These bearings are cast in the shop, on a brass back, and after being fitted in place are carefully lined and reamed to the proper size. Scraping is practically unknown, as is now the case in nearly all the better grade automobile shops.

There are a great variety of breakages from various causes. Among these is the breaking of the piston pin, which usually destroys the piston and frequently breaks the small end of the connecting rod. This is probably caused by the piston pins being case hardened too deep, which makes them brittle, owing to the lack of the soft core, as these pins are hollow.

The bearing of these pins is in the aluminum piston, as has previously been described in connection with the building of the Curtiss motor. These wear in time, and oversize piston pins are being tried to remedy this difficulty. Bronze bushings may also be adopted later in case of further wear, or if the enlarged pins do not prove entirely satisfactory.

Crankshafts are frequently bent when the propeller strikes the earth in making a bad landing, and a special 35-ton hydraulic press is being installed for straightening these shafts. It is the intention to clamp the end shaft bearings in a suitable fixture and apply pressure wherever it may be necessary in order to bring the shaft back to its normal position or to within 0.002 inch of straight. If the shaft is over 0.020 inch out of line, it is not usually considered advisable to attempt straightening.

REPAIRING CRANK CASE BY WELDING

When a crankshaft becomes bent from an accident of this kind, it usually cracks or otherwise mutilates the crank case or engine face, or both. Many of these can be repaired by an expert oxyacetylene welder, but it is very necessary to hold the pieces firmly in position to prevent their being badly warped by the local application of intense heat. To avoid this, heavy cast-iron blocks are to be used, to which the cases will be bolted

ROYAL FLYING CORPS
(MILITARY WING)

NOTES FOR THE GUIDANCE OF MECHANICS IN CHARGE OF AEROPLANES.

The following Notes will assist Mechanics in charge of the Rigging and Engine of an Aeroplane in the methodical carrying out of their duties. They are a guide. It must not be assumed that these are all the points to be attended to.

GENERAL NOTE.
RIGGERS AND FITTERS.

Mechanics who have charge of a machine are primarily responsible for its safety while under their charge. They should constantly try to think of new methods to ensure this. They should invariably bring any fresh points to the notice of their Flight Commander, in order that the rest of the Corps may benefit by them. They should always try to find out the cause of anything wrong, and inform the officer in charge of the machine of their opinion. They should bear in mind any particular incidents which may have happened to the machine under their charge during each flight, and be on the look-out for signs of stresses that may have occurred to the machine in consequence of these incidents. For example--a steep spiral may cause side strains on the engine bearers; a flight in bad weather may cause bending stresses on the longitudinal members of the body, besides stretching the lift and drag wires, &c. No part of a machine can be safely overlooked, and good mechanics will always be seeking for the possible cause of accidents and bringing them to the notice of the officer in charge of the machine

No alteration or repair is to be made to a machine without first reporting to, and obtaining the sanction of, the Flight Commander

NOTES FOR MECHANICS IN CHARGE OF RIGGING.
DAILY INSPECTION

Carefully examine :—

All struts and their sockets, longerons, skids, &c.

All outside wires and their attachments.

All control levers or wheels, control wires, and cables and their attachments.

(The control cables should not be too tight, otherwise they will rub stiffly in the guides. The control lever should be set central in the aeroplane body, or in a convenient position for the pilot when controls are neutral—*i.e.*, position for flying level—and should give a good range of elevator movement up and down. The full amount of warp each way should be obtainable. Pay special attention to cables and control wires where they pass over pulleys or through guides, and to all split pins; pass the fingers both ways over cables to see if there is any sign of fraying; keep the pulleys well lubricated with thick oil and the guides well greased.)

All splices for any signs of their drawing.

Lift and under-carriage cables for any signs of stretching.

All fabric, whether on wings or other parts of the machine, for holes, cuts, weak or badly doped places, or signs of being soaked with petrol, and to see if it is properly fastened to the wings, &c.

All outside turnbuckles, to see that they have sufficient threads engaged, and that they are properly locked.

Axles, wheels, shock-absorbers, and tyres, pumping the latter up to the correct pressure.

The seats, both for passenger and pilot, seeing that the fastenings are correct.

Safety belts and their fastenings.

All instruments and their fastenings.

The daily examination should be carried out systematically in the following order :—

(*a*) Lower wings, under-carriage complete, tail-planes, with all wires attached to these, tail-skids and all attachments and rudder.

(*b*) Nacelle or body, bolts of lower plane, all control levers and wires.

(*c*) Top wings, wing-flaps and wires.

AFTER EACH FLIGHT.

Carefully examine :—

The under-carriage, tail-skid and attachments, and lift and drag wires, for tautness.

The wheels, after a rough landing, for bent spokes, uncovering them if necessary.

After flying is finished for the day, wipe all the oil off the planes as far as possible with a cloth or cotton waste. ***Petrol must not be used for this purpose.***

WEEKLY INSPECTION.

Check over all dimensions, span, chord, gap, stagger of wings, angle of incidence of wings and tail, dihedral angle; alignment of body, rudder and elevators, and the general truth of the machine.

Examine the points of crossing of all wires to see there are no signs of wear, and that each wire is properly bound with insulating tape to prevent rubbing.

Examine all places where wires cross the struts, and see if the plate requires renewal.

Examine any control wires which are bound together, and see that they are correct. (Insulating tape should be used for this in preference to wire, as the latter may slip and cause a lock.)

Examine the wheels for bent or loose spokes, uncovering them for this purpose, if they have covers fitted.

NOTES FOR MECHANICS IN CHARGE OF ENGINES.
DAILY INSPECTION

Carefully examine :—

All control wires belonging to the engine and all electric connections, wires and switches. See that both switch and throttle stop the engine.

Petrol and oil tanks, pipes and gauges. See that the copper pipes are not crystallized, and rub metal ones are not perished.

Pay particular attention to the connection of petrol and oil pipes to see that they are tight, and to cocks to see that they are in working order.

BEFORE EACH FLIGHT.

Examine airscrew thoroughly to see if it is correct, and that the nuts are tight.

Test pressure pump (if any) and fill the top tank.

Check the amount of oil and petrol in tanks.

FIG. 181.

so as to hold them firmly in position during the welding operation. In this connection it is interesting to note that a large heating furnace has been provided into which the crank case, already bolted on its heavy cast-iron form, can be heated as hot as may be necessary, before the welding is attempted. This, in some instances, is about 200 degrees below Fahrenheit, the melting point of the alloy, as this temperature has been found to assist the welding to a large degree and also to prevent warping after the piece is removed from the cast-iron form.

There is also considerable repair work on the engine radiators, which means sheet-metal work, soldering and brazing to a considerable extent. In all the repair departments it is necessary to exercise extreme care, particularly when green men are being broken in.

SECTION XXIII

INSTRUMENTS FOR AIRPLANES

The aviator requires a number of instruments to insure proper handling of the machine. Some of these are necessary because the aviator has no means of knowing his exact position without

FIG. 182.

them. High in air, or in the clouds with no sight of land, he cannot tell when he is flying level, climbing too steeply or banked to a dangerous degree, without some instruments to tell him his position.

These instruments are: tachometer or engine speed indicator, hich sometimes includes a counter to give total engine revolutions; ›mpass; clinometer; banking indicator; incidence indicator; timeter; radiator thermometer; air speed indicator; drift indi-.tor; stabilizer; clock; map board; engine controls; fuel and bricating gages; ignition switches, bomb sighting and dropping echanism; camera and machine gun.

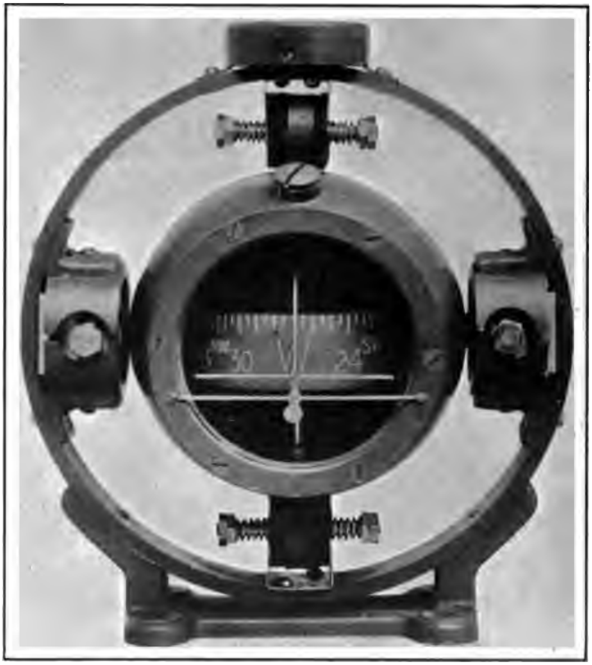


FIG. 183.

The tachometer is practically a speedometer similar to those ;ed in automobiles.

The compass aids in navigation as at sea, two types being .own in Figs. 182 and 183. These are Creagh-Osborne liquid ›mpasses, Fig. 182, being of the usual horizontal type. The ner bowl is filled with a mixture of alcohol and distilled water, the compass card floating in the liquid. The inner bowl rests on horse hair which acts as a spring to absorb vibration.

The mixture of liquid for air compasses varies from 45 per cent. alcohol and 55 per cent. of water to almost pure alcohol. The high percentage of alcohol is to prevent freezing at high altitudes.

In shipping liquid compasses, the jar due to transit almost invariably causes bubbles to appear in the liquid. This can be readily remedied by carefully removing the inner bowl, taking out the filling plug and adding a few drops of either alcohol or distilled water with a medicine dropper or fountain pen filler. This applies to both types of compass.

In the second compass shown, the graduations are on the outside rim of a ring which is mounted on the float. This float is centered on a suitable jeweled pivot in both cases.

This compass is held in the outer ring by means of the four spring mountings shown. These also contain soft iron cores with which to correct certain compass errors, while the small round compartment on top holds permanent magnets when necessary, to correct other errors. The correction of these errors can hardly be taken up here, as it requires long experience to insure success.

The small arrow on the wire across the face of the compass can be set to allow for the drifting of the plane. The vertical white line is a wire from which the readings are taken. The horizontal line acts to some extent as a banking indicator by showing when the machine is out of the horizontal. The indicating wires and the figures and graduations on both compasses are painted with radium material so as to show at night with no outside illumination.

The Sperry Clinometer is shown in Fig. 184. This is mounted on the back side of the dash with the small round portion projecting through. This shows the angle of the plane with the horizontal and shows the aviator whether the angle is safe for his plane. The scale is on the rim of a wheel which is weighted and the case turns around the wheel.

A very neat instrument is the Sperry banking indicator in Fig. 185. The outline of the airplane is set level with the machine and the white bar is connected to a pendulum inside the case. When the plane is banked for a turn the pendulum flies to the outer side of the circle and swings the white line out of the horizontal just in proportion to the radius and speed of the turn.

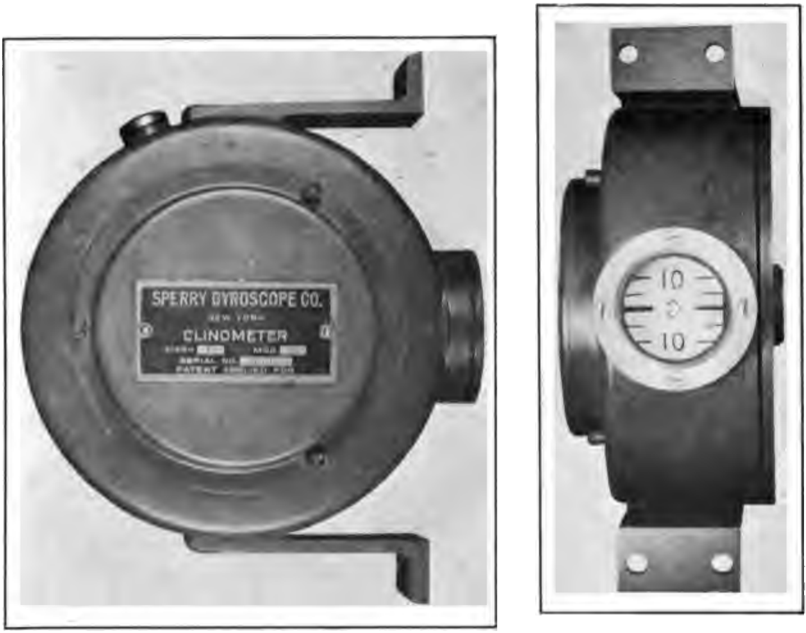


FIG. 184.

If the airplane is banked the proper amount, the white line and the outline of the plane will be parallel the same as when the machine is level.

If the plane is not properly banked for the turn, the lines will show which way the machine should be tipped and how much. It is a very simple device and very efficient. The two screws allow adjusting to the plane without requiring too careful work in mounting.

Fig. 185.

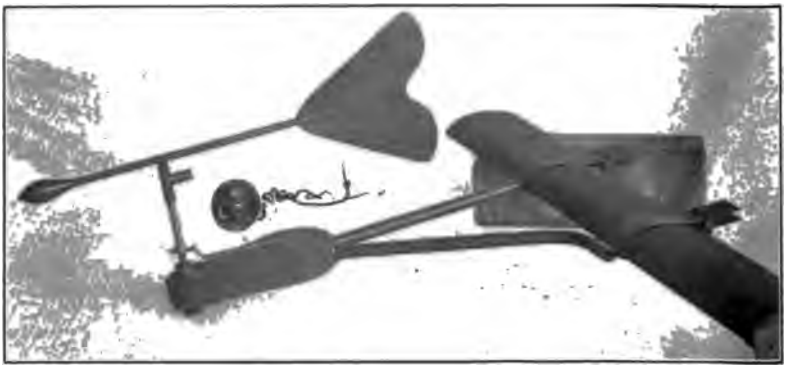


Fig. 186.

A very necessary instrument is the Clark angle of incidence indicator in Fig. 186. This fastens to one of the struts between the wings, preferably so that the pointer and scale can be seen the pilot. The vane is so proportioned that it remains level en the plane is in motion.

Electrical connections run to the round indicator shown, this ng located on the dash, and containing three lamps, green, red, l white. The indicating valve is so adjusted that when flying el no light burns. When climbing the *green* light shows en the proper climbing angle for best efficiency is reached.

FIG. 187.

If this climbing angle is increased to the stalling point—which the danger point, the *red* light signals the aviator to decrease angle.

Should he volplane (or glide) at too steep an angle and attain a ngerous speed, the *white* light is shown.

The three lights give a positive tell-tale as to flying conditions l make this a particularly valuable instrument.

THE CLOCK

A high grade, jeweled clock is also an important part of the equipment of a modern airplane as correct timing is very necessary for nearly all military operations.

ALTIMETER OR ALTITUDE BAROMETER

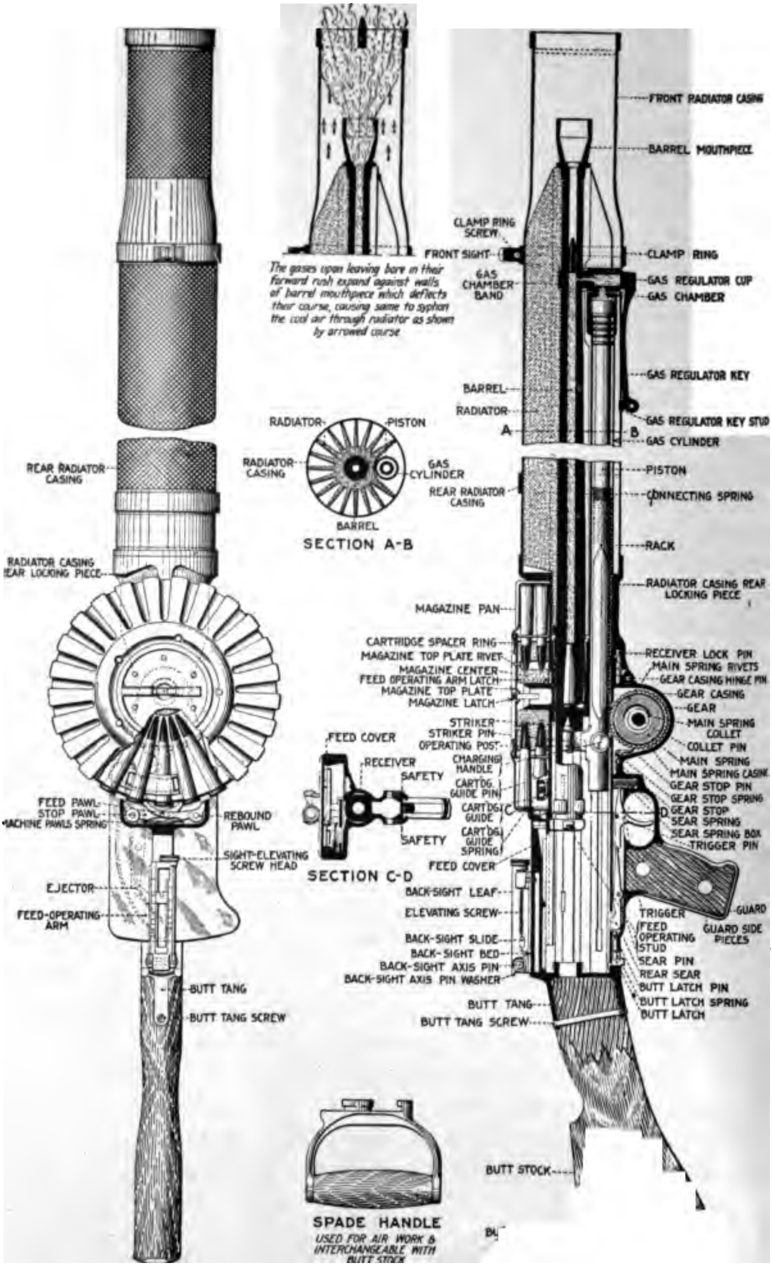
This instrument, Fig. 187, shows the height of the airplane above the earth. It contains a metal vacuum box or chamber which is acted on by the varying density of the atmosphere. This actuates a hand and shows the height on the dial. The dial is adjusted to zero on the ground so as to show the flying height at that altitude. The lock shown holds the dial in the position set. The dial diameter is about 4 inches and both dial and hand are made luminous in the dark by radium material.

SECTION XXIV

THE LEWIS MACHINE GUN

The Lewis machine gun is used very largely in airplane work and has proved very successful. It is a gas-operated gun and has a positive air-cooling device somewhat along the lines of the Franklin method of cooling gas-engine cylinders. It has a rotating drum magazine which holds 47 cartridges and double drums are also used holding 50 more than this number. The gun alone weighs 26 pounds 12 ounces and with the army tripod and magazine in place it weighs 30 pounds 2½ ounces. For airplane use it has a special gun mounting which allows it to be easily swivelled into almost any position. See Fig. 188.

The barrel is surrounded by, and throughout its length is in direct metallic contact with, an aluminum radiator. The radiator has high longitudinal radial fins, and it is inclosed in a steel radiator casing that is open at both ends and extends forward beyond the muzzle of the barrel. The barrel mouthpiece, secured to the barrel by a left-handed thread, contains a cup-shaped aperture designed to direct the muzzle blast into the forward extension of the radiator casing so as to induce suction of air from breech to muzzle inside the radiator casing and along the surfaces of the fins. Near the barrel muzzle and in its under side is a port through which powder gas at barrel pressure is admitted during the time required for the bullet to pass from the port to the muzzle. The powder gas passes into a gas chamber and thence into a gas cylinder beneath the barrel and parallel with it, in which it drives a piston rearward. The piston is pinned securely to the rack, which is provided with teeth on its lower surface meshing with teeth in the periphery of the gear.


The gases upon leaving bore in their forward rush expand against walls of barrel mouthpiece which deflects their course, causing same to syphon the cool air through radiator as shown by arrowed course
FRONT RADIATOR CASING
BARREL MOUTHPIECE
CLAMP RING SCREW
FRONT SIGHT
CLAMP RING
GAS CHAMBER BAND
GAS REGULATOR CUP
GAS CHAMBER
GAS REGULATOR KEY
BARREL
RADIATOR
GAS REGULATOR KEY STUD
A
B
GAS CYLINDER
PISTON
CONNECTING SPRING
REAR RADIATOR CASING
RACK
RADIATOR CASING REAR LOCKING PIECE
RADIATOR
PISTON
RADIATOR CASING
GAS CYLINDER
BARREL
SECTION A-B
REAR RADIATOR CASING
RADIATOR CASING REAR LOCKING PIECE
MAGAZINE PAN
CARTRIDGE SPACER RING
MAGAZINE TOP PLATE RIVET
MAGAZINE CENTER
FEED OPERATING ARM LATCH
MAGAZINE TOP PLATE
MAGAZINE LATCH
RECEIVER LOCK PIN
MAIN SPRING RIVETS
GEAR CASING HINGE PIN
GEAR CASING
GEAR
MAIN SPRING COLLET
COLLET PIN
MAIN SPRING
MAIN SPRING CASING
GEAR STOP PIN
GEAR STOP SPRING
GEAR STOP
SEAR SPRING
SEAR SPRING BOX
TRIGGER PIN
STRIKER
STRIKER PIN
OPERATING POST
CHARGING HANDLE
CARTDG. GUIDE PIN
CARTDG. GUIDE
CARTDG. GUIDE SPRING
C
D
FEED COVER
RECEIVER
SAFETY
SAFETY
SECTION C-D
FEED COVER
FEED PAWL
STOP PAWL
MACHINE PAWLS SPRING
REBOUND PAWL
SIGHT-ELEVATING SCREW HEAD
EJECTOR
FEED-OPERATING ARM
BACK-SIGHT LEAF
ELEVATING SCREW
BACK-SIGHT SLIDE
BACK-SIGHT BED
BACK-SIGHT AXIS PIN
BACK-SIGHT AXIS PIN WASHER
TRIGGER
GUARD
FEED OPERATING STUD
GUARD SIDE PIECES
SEAR PIN
REAR SEAR
BUTT LATCH PIN
BUTT LATCH SPRING
BUTT LATCH
BUTT TANG
BUTT TANG SCREW
BUTT TANG
BUTT TANG SCREW
BUTT STOCK
SPADE HANDLE
USED FOR AIR WORK & INTERCHANGEABLE WITH BUTT STOCK

The receiver is secured to the barrel by a large square thread and is pierced longitudinally by two bores, one above the other. These bores are connected by a narrow slot from the rear of the receiver almost to its front end. The piston travels in the lower bore of the receiver, which forms a rearward extension of the gas cylinder under the barrel. The upper bore in the receiver forms the boltway in which the bolt travels. The bolt is suspended on and operated by the striker post at the rear end of the rack. The striker is pinned in the striker post, which fits into a cam slot in the bottom of the bolt. This slot is cut away toward the axis of the bolt for the striker, and the face of the bolt is pierced axially from this slot to permit the striker to reach the primer of the cartridge in the chamber. Suitable delays in the action, after locking the bolt and before firing, and after firing and before unlocking, are provided by the longitudinal portion of the slot for the striker post in the bottom of the bolt. Locking and unlocking are accomplished by the cam angles at the rear of the slot in the bolt. Breech closure is by rotary locking, the breech bolt having four locking lugs that are turned in the corresponding locking recesses in the receiver. Under the receiver at its front end is fitted the gear case, which contains the gear and the mainspring. The latter is of the ribbon type and is wound up on the opening, or rearward, stroke of the action by the meshing of the teeth of the gear with the corresponding teeth under the rack. The spring tension so obtained is the means for the closing stroke of the action by rotating the gear in the opposite direction and so driving the rack, which is part of the piston, forward.

Above the receiver and pivoted on the magazine post is the feed-operating arm. It is driven by the upper lug of the feed-operating stud (attached to the rear of the bolt and with its upper lug travelling in a slot through the upper surface of the receiver), which engages a groove under its curved rearward extension so as to swing the feed-operating arm to the left during the opening movement of the bolt and to the right during its closing movement. The feed pawl on the feed-operating arm engages and rotates the magazine, and the cartridge opening in the feed-operating arm receives and guides the cartridge delivered to it.

The feed cover is secured to the top of the receiver. At the rear end it carries the rear sight base, and under its front edge are fitted the stop and rebound pawls and their spring. The function of the stop pawl is to engage with an outer projection of the magazine pan, which is rotated by the feed pawl on the operating arm, and prevents too great a movement. The rebound pawl engages with another projection of the magazine pan and prevents its rotation in the reverse direction, so that the magazine is accurately indexed and positively locked by each cycle of operation. A forward projection at the left side of the feed cover carries the cartridge guide, to which the feed-operating arm delivers the cartridge in loading.

The bolt carries two extractors lying in recesses in its top and side, and the ejector is pivoted in a recess in the receiver at the left of the boltway. The piston is operated by hand by the charging handle, which is fitted in it at the rear of the receiver when the buttstock is removed and which travels in the slot in the left side of the receiver. The safety is a plate sliding vertically in ways on the left side of the receiver. In its upper edge are two recesses designed to engage with the charging handle, one in its forward (uncocked) and the other in its rearward (cocked) position. To put the gun when cocked on safe, raise the safety and pull the trigger. The charging handle engages in front of the recess in the safety and prevents its accidental movement. This locks the gun against operation or discharge. To put the gun in action, draw back the charging handle to cock and press the safety down. The safety also, when raised, closes the slot in the left side of the receiver, in which the charging handle travels, and prevents sand, mud, dust, etc., from getting into the action.

The trigger is contained in the guard, which is a pistol-grip form. It is attached to a sear which, when the trigger is released, engages a notch in the under side of the rack and holds the action open at the very beginning of the closing stroke. The buttstock is usually of a form similar to a rifle buttstock, but a spade grip may be supplied. Either rifle buttstock or spade grip is attached by interrupted thread to the boltway in the rear of the receiver. The butt-tang or spade-grip tang locks up the entire rear end of the receiver and takes the thrust of the recoil of the piston.

THE MAGAZINE

The magazine is a circular steel drum in which the cartridges are arranged radially, bullet ends toward the center. The magazine center is of aluminum. It has a deep spiral groove in it, in which the bullet ends of the cartridges engage and by which they are controlled. When the magazine is latched in place on the magazine post, the magazine center is keyed to the magazine post and held stationary. The magazine pan carrying the separator pins and the cartridges is rotated around the center during the operation of the gun, so that the spirally arranged column of cartridges is driven down the groove of the magazine center until each cartridge is successively reached by the feed-operating arm.

The action of the gun is as follows: Commencing with the gun in the "ready to feed" position, a filled magazine being latched on the magazine post and the charging handle having been drawn fully to the rear by hand so that the sear engages the rack and holds it back, the trigger is pressed. This releases the rack, which is driven forward by the spring-actuated rotation of the gear.

The striker post, by pressure of its neck against the left side of the cam slot in the bolt, drives the bolt (which cannot be cammed around because of its lugs travelling in the correspondingly shaped grooves in the boltway) straight forward in the boltway. The feed-operating stud carried forward with the bolt cams the feed-operating arm to the right, the feed pawl slipping over a r post, driven still farther rearward in the bolt, strikes with ht side the cam surface in the right side of its slot in the camming the bolt to rotate from right to left, turning the g lugs out of their recesses. The striker post now reaches ear of its cut in the bolt, and its further travel carries the directly back with it; the empty shell is held in the grip of xtractors till the feed-operating stud strikes the rear of the r.

e top lug of the feed-operating stud, travelling in the groove under side of the feed-operating arm, cams the feed-operating m so that it swings across the top of the receiver from right t. The feed pawl, acting against one of the outer projec- of the magazine pan, carries the magazine around suffi- y to drive the first cartridge down into the cartridge open- n the feed-operating arm by the rotation of the magazine and interior separators around the stationary, spirally ed magazine center. The cartridge opening of the feed- ting arm, with the cartridge it has just received, now com- es to pass under the upward projecting arms of the feed , which carry the cartridge guide; and these arms commence ntrol the cartridge as soon as it leaves the magazine. Fur- eftward travel of the feed-operating arm brings the car- as soon as it leaves the magazine. Further leftward of the feed-operating arm brings the cartridge the cartridge guide and its downward spring tension. At oint, the spring stud on the feed-operating arm clears the pawl, which is then pressed forward by its spring and nts further rotation of the magazine.

e lug on the left of the feed-operating stud now strikes the nd of the ejector, driving it into its slot and pivoting the of the ejector out so that it strikes the side of the empty shell. has still been carried by the extractor, and throws it gh the ejector port out of the receiver to the right.

ward the end of the rearward travel of the rack, the bent nward projection of the lower surface of the rack whose projection on the rim of the magazine and engaging behind it. The spring stud on the feed-operating arm presses the stop pawl back to prevent its intercepting a projection of the magazine. The head of the bolt now reaches the head of the ejector, which it presses back into the ejector cut, causing the rear of the ejector to be pivoted out into the boltway behind the bolt. The face of the bolt now strikes the base of the cartridge, which is held ready for it in the loading ramps of the receiver, and it drives the cartridge before it into the chamber. The extractors spring over the rim as soon as the cartridge seats. Just as the cartridge seats, the locking lugs of the bolt clear the front of the cruciform part of the boltway formed by their guide grooves and reach their locking recesses. The bolt face now lies against the rear end of the barrel and the head of the cartridge, and the striker post still pressing against the left side of the cam slot in the bolt now cams the bolt to the right, turning the locking lugs fully into the locking recesses of the receiver. As the bolt locking is completed, the striker post enters the longitudinal front part of its cut and carries the striker against the primer of the cartridge in the chamber, firing the cartridge.

THE EFFECT OF FIRING

Firing develops the power for another cycle of operations. As soon as the bullet has passed the gas port near the muzzle of the barrel, gas under pressure is driven through the gas port into the gas-chamber gland and chamber and through the hole in the gas-regulator cup onto the head of the piston, driving it rearward in the gas cylinder. Driving the rack teeth back over the gear teeth with which they mesh rotates the gear and extends the mainspring during the entire opening movement. During the first 1⅓ inches of rearward travel the striker post moves back with a longitudinal part of its cut in the bolt, withdrawing the point of the striker from the face of the bolt, the bolt remaining locked and stationary. In the next ⅔ inch of travel the striker post, driven still farther rearward in the bolt, strikes with its right side the cam surface in the right side of its slot in the bolt, causing the bolt to rotate from right to left, turning the locking lugs out of their recesses. The striker post now reaches the rear of its cut in the bolt, and its further travel carries the bolt directly back with it; the empty shell is held in the grip of the extractors till the feed-operating stud strikes the rear of the ejector.

The top lug of the feed-operating stud, travelling in the groove in the under side of the feed-operating arm, cams the feed-operating arm so that it swings across the top of the receiver from right to left. The feed pawl, acting against one of the outer projections of the magazine pan, carries the magazine around sufficiently to drive the first cartridge down into the cartridge opening in the feed-operating arm by the rotation of the magazine pan and interior separators around the stationary, spirally grooved magazine center. The cartridge opening of the feed-operating arm, with the cartridge it has just received, now commences to pass under the upward projecting arms of the feed cover, which carry the cartridge guide; and these arms commence to control the cartridge as soon as it leaves the magazine. Further leftward travel of the feed-operating arm brings the cartridge as soon as it leaves the magazine. Further leftward travel of the feed-operating arm brings the cartridge under the cartridge guide and its downward spring tension. At this point, the spring stud on the feed-operating arm clears the stop pawl, which is then pressed forward by its spring and prevents further rotation of the magazine.

The lug on the left of the feed-operating stud now strikes the rear end of the ejector, driving it into its slot and pivoting the head of the ejector out so that it strikes the side of the empty shell, which has still been carried by the extractor, and throws it through the ejector port out of the receiver to the right.

Toward the end of the rearward travel of the rack, the bent (downward projection of the lower surface of the rack whose space forms the cocking notch) rides over the nose of the sear, temporarily depressing it against the tension of the sear spring, which immediately rises again. The rear end of the rack then strikes the butt tang, terminating the opening stroke. The feed-operating arm is now at the extreme left, the cartridge has been brought over the cartridge opening in the top of the receiver against which the cartridge guide presses it, the rebound pawl engages an exterior projection of the magazine so as to prevent backward rotation, and the mainspring is in full tension.

If after its first pressure the trigger has been instantly released, the piston and rack will be intercepted by the engagement of the nose of the sear with the cocking notch or bent in the lower edge of the rack, suspending the operation of the gun in the "ready to feed" position. If pressure has been maintained on the trigger, the closing stroke will instantly be repeated; and automatic operation of the gun will continue until the cartridges in the magazine are exhausted or pressure is removed from the trigger.

Feed is absolutely positive and unaffected by the position of the gun. The cartridge is under complete mechanical control during every stage of feeding. The functioning of the gun is unaffected by pointing it straight up or straight down or turning it on its side or upside down. Ejection is also positive.

The forms of gas port, regulator cup, cylinder and piston permit functioning the gun by a materially smaller volume of gas and at much lower pressure than in gas-operated mechanisms of previous design. As a result, shock and strain of parts are minimized, and retraction of the breech mechanism by hand is facilitated.

The gun may be entirely dismounted without other tools than a cartridge and a small spanner. Removing the buttstock and withdrawing the rack, piston and bolt leave the barrel and cylinder ready for cleaning. This permits inspection of the barrel or insertion of the cleaning rod into the barrel from either end.

Semi-automatic fire (single shots) or automatic fire may be *obtained* at will without extra parts or special adjustment.

Vibration of the barrel is so damped and broken up by the radial support afforded the barrel by the mass and structure of the radiator that single shots are fired on the same line of sight as that of full automatic fire.

The muzzle blast, directed by the barrel mouthpiece onto the interior of the radiator casing in front of the muzzle to induce the air current through the radiator, exerts a forward pull on the radiator casing which neutralizes the recoil to such an extent that the gun may be fired from the shoulder with accuracy and without inconvenience.

The absence of recoil and vibration permits satisfactory use with a very light mount or with no mount.

The gun is absolutely mobile. Besides its ability to function normally at any angle or in any position, it may be carried, loaded and locked by one man, who can commence firing as quickly and easily as with the Model 1903 service rifle.

A magazine may be placed on the magazine post and latched, or may be unlatched and removed with one hand. The magazine latch is conveniently operated by the thumb of the hand that puts the magazine on the magazine post or removes it from the post. No delicate adjustment is necessary in putting the magazine on the post and preparing to fire, and it may be done with as much speed in total darkness as in daylight.

The new model Lewis airplane gun has no radiator. This has been adopted for U. S. airplanes.

SECTION XXV

TABLES AND DIAGRAMS

MEASURING THE CONTENTS OF HORIZONTAL CYLINDRICAL TANKS

In a horizontally disposed cylindrical tank the contents cannot be measured without the knowledge of certain geometrical relations existing between the height at which the liquid stands and the volume it occupies. These are given hereafter: first,

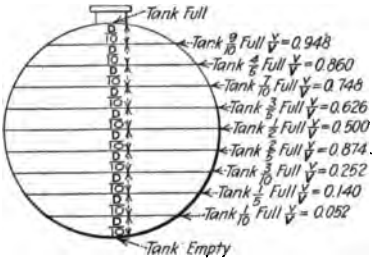


FIG. 189.—Tank divided into 10 parts of equal height. (Case in which measurement is taken with an ordinary foot rule.)

in relation of volume to height; second, in relation of height to volume.

$V =$ total volume of tank;
$v =$ volume occupied by liquid;
$D =$ diameter of tank;
$h =$ height of liquid in tank.

Examples

1. To find the capacity of a tank 12 inches in diameter by 40 inches long.

The ordinate corresponding to 12 intersects the "Curve Gallons per Inch of Length" at 0.49 inch. Multiplying 1 by 40 we find the capacity of the tank would be 19.6 gallons.

2. To find the distance above the bottom of the stick (ta in inches for any number of gallons.

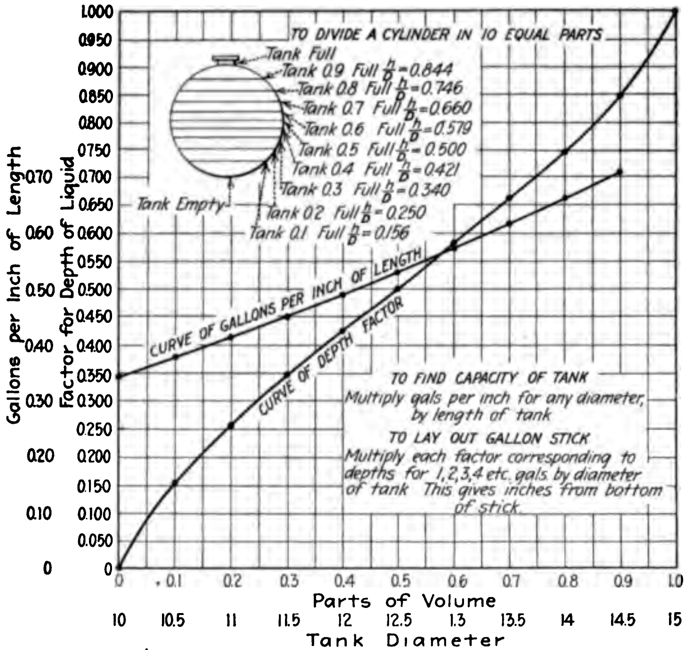


FIG. 190.—Curves to lay out a stick to measure contents of a horizontal cy drical tank. (*H. L. Pope.*)

Assume that a tank 12 inches in diameter and 40 inches lc having a capacity of 19.6 gallons (as previously found) conta 3 gallons.

The decimal proportion of the total volume occupied by

$$\text{gallons} = \frac{3}{19.6} = 0.153.$$

The ordinate corresponding to this value intersects the "Curve of Depth Factor" at 0.213.

Multiplying this by 12, the depth or diameter, we have 2.556 or approximately 2 9/16 inches above the bottom.

CONTENTS OF CYLINDRICAL TANKS

Gasoline or other tanks are frequently of various shapes in order to fit into available openings in the machines. These require special measuring devices adapted to their peculiar shape. But as round tanks are used wherever possible and it is convenient to know how much they contain at various times, the accompany-

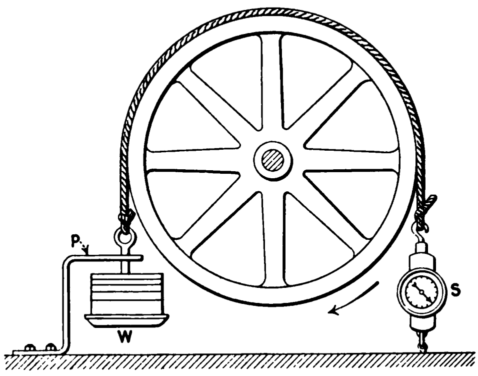


FIG. 191.

ing diagram may be of service in some cases. This enables one to measure the contents of a cylindrical tank with very little trouble if a stick is graduated in accordance with this diagram. These show how to measure with either a foot rule or how to graduate a stick for the purpose of giving direct readings.

ROPE BRAKE DYNAMOMETER FOR ENGINE TESTING

Although the power of an engine is usually tested by noting the number of revolutions which it will drive its propeller, it is sometimes desired to know the brake horsepower which is being developed. Fig. 191 gives two views of a rope brake dynamometer recommended by the S. A. E. with full information as to how it is to be used, the proper rope size of, the working tension, angle of contact and all necessary data. This also tells when it can be used without water-cooling and when water becomes necessary.

Fig. 191 shown above consists of a weight W (pounds) suspended by the rope and guarded against upward motion by stop P. The scale S records the counterpull in pounds at the other end of the rope. With the speed N of the pulley in r.p.m. and the radius R of the pulley in feet, the brake horsepower developed is:

$$\text{B.HP.} = \frac{2\pi RN\,(W\text{-}S)}{33{,}000}$$

which reduces to the form:

$$\text{B.HP.} = 0.00019\,RN\,(W\text{-}S)$$

Fig. 192 is somewhat more elaborate and consists of a platform scale supporting a frame which carries the rope and has a hand-

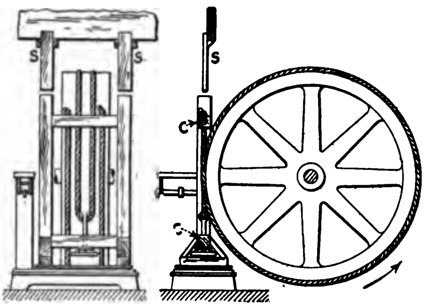


FIG. 192.

wheel as shown for adjusting its tension. This lends itself readily to the measurement of larger powers where a number of parallel strands of rope need to be used. With the scale reading W (pounds) and the weight K (pounds) of the frame mechanism on the platform, the brake horsepower developed is:

$$\text{B.HP.} = 0.00019\,RN\,(W\text{-}K)$$

in which R and N have the same significance as in the preceding formula.

The amount of energy which can be radiated from a given brake depends upon the amount and nature of its surface as well as its linear speed. A rule to determine the necessity of water-cooling is as follows:

Multiply the width of the pulley face in inches by its linear speed in feet per minute and divide by the horsepower to be absorbed. If the quotient exceeds 900, air-cooling will do. It is is between 400 and 900, the brake should be water-cooled. If less than 400, the pulley is too small.

To determine the maximum tension on the rope, and from this the size required, find first the effective pull in pounds which is:

$$\text{Effective Pull} = \frac{5250\,H}{RN}$$

in which H is the horsepower to be absorbed, R is the radius in feet of the pulley, and N is the speed in r.p.m. of the pulley.

The effective pull is the difference between the tensions on the two ends of the rope and can be used with the following table to determine the tension in the tight side, that is, the maximum tension.

Total angle of contact of rope, degrees	Ratio of maximum tension to effective pull	Ratio of maximum to lesser tension
180	1.40	3.50
270	1.18	6.59
360	1.09	12.30
450	1.05	23.20
540	1.02	43.40

Knowing the angle of turn or the total angle of contact of rope and drum or pulley, it is easy to select the corresponding constant in the second column with which to mutiply the effective pull in order to secure the value of the maximum tension.

It then remains to select a rope or several strands of rope whose combined strength corresponds to the working tensions given in the following table:

Diameter rope (inches)	Working tension (pounds)
½	300
⅝	450
¾	700
⅞	1,000
1	1,300
1⅛	1,700
1¼	2,100

A fan dynamometer used quite successfully in automobile practice is shown in Fig. 193. The parts are:

(*A*) Dynamometer shaft.

(*B*) Universal joint yoke integral with *A*.

(*C*) Johnson bar or universal shaft which connects engine to dynamometer.

(*D*) Arms of dynamometer, a solid bar of nickel steel.

(*E*) Fan blades, heavy sheet aluminum. These have sections of angle iron permanently riveted to the blades, the angles being placed back to back and spaced the thickness of the arm *D*.

(*F*) Hub, securely keyed to shaft and slotted for arm *D*. Nickel steel.

(*G*) Heavy cast-iron frame supporting shaft *A*.

(*H*) Cast-iron cap for sleeve *N*.

(*I*) Extension of shaft *A*, to drive tachometer.

(*J*) Weston electrical tachometer, generator unit.

(*K*) Flexible connection to tachometer.

(*L*) Heavy cast-iron bed plate supporting engine and dynamometer.

(*M*) Protecting cage, wire netting.

(*N*) Cast-iron sleeve in which *A* is mounted on heavy annular ball bearings. Slidable endwise to facilitate quick universal connection with engine through *C*. Retained in position when dynamometer is in use by hinged clip *O*, which then fits into the space between collar on *N* and cap *H*.

(*O*) Hinged clip above referred to.

(*P*) Holes in *D* regularly spaced, for adjustment of *E*.

(*Q*) Universal engine stand, easily adaptable to the several sizes of engines produced.

(*R*) Nickel-steel bolts securing *E* to *D*.

As a matter of precaution against the very high stresses that

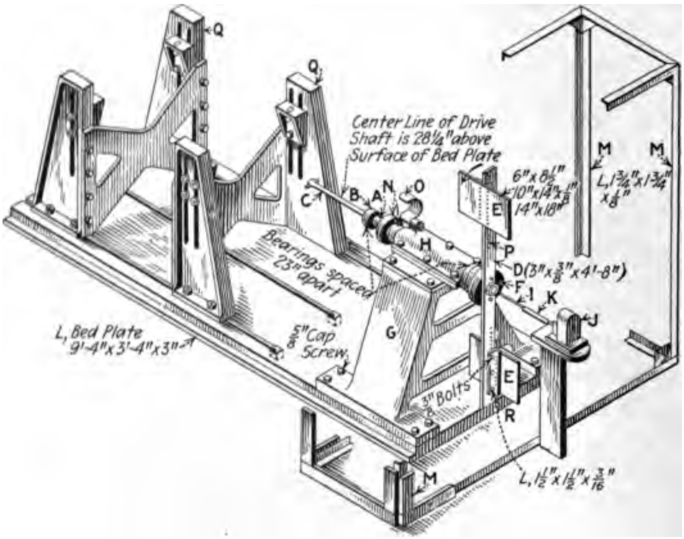


Fig. 193.

are set up in the dynamometer at high speeds, it has been found advisable to have the arms, hub, and bolts securing the blades to the arm all of 3½ per cent. nickel steel. A cage of ½-inch mesh wire netting 6 feet high was also built, enclosing the field of the rotating arms and blades, to prevent accidents.

The proximity of the dynamometer to surrounding objects is of some importance. It should be placed so as to be at least

6 to 8 feet from a side wall or ceiling; that is, there should be considerable free air space all around the field of the rotating blades. The presence of the wire netting cage undoubtedly has some effect on the dynamometer, but as this is a constant and included in the calibration it may be neglected.

SPECIFIC GRAVITY AND WEIGHT OF WOODS

The extensive use of wood in airplane construction and the possibility that substitutes may have to be found for ash, spruce and black walnut, makes it advisable to know something about other varieties of woods and their qualities. The following table gives both the specific gravity and the weight of a large number of more or less well-known woods.

STANDARDIZING AIRCRAFT WORK

With all parts standardized, it would be possible to turn out airplanes in much the same way as the modern automobile factories turn out their standard product, except that in this instance the quantity is not sufficient to allow of special machinery or of machinery of any kind for some of the more complicated metal shapes. These must be constructed more or less by hand, with the aid of forms, filings jigs and bending fixtures, and in some cases the old art of forming sheet metal with the mallet is called into play on the special shapes required. An example of this kind of work is the upper part of the hood, or casing, which fits over the engine, the sides of this hood being formed in graceful curves to accommodate some of the valve mechanism and other parts at the top of the engine. This forming is done quite easily with the sheet aluminum used, the sheet being clamped over a form and drawn to the desired form with a round-faced mallet. In a similar manner the gasoline pocket in the under sheet of the hood is drawn up quickly and in perfect contour, to insure that all the surplus gasoline drains away and does not accumulate and possibly cause trouble.

The fuselage is built up in the regular way except that special fittings have been devised for the turnbuckle connections at each fuselage strut. Ash is used for the longerons and spruce

TABLE I.—BENDING ALLOWANCE FOR SHEET METAL

Thickness	20, 22 B.W.G.		1/32 Aver. T = 0.03142			
Degrees	15	30	45	60	75	90
Radius						
1/32	0.0115	0.023	0.0345	0.046	0.0575	0.069
1/16	0.0196	0.0392	0.0588	0.0784	0.098	0.1176
3/32	0.028	0.056	0.084	0.112	0.140	0.168
1/8	0.036	0.072	0.108	0.144	0.180	0.216
3/16	0.0524	0.1048	0.1572	0.2096	0.262	0.314

Thickness	12 B.W.G. 3/32		1/10 Aver. T = 0.1009			
Degrees	15	30	45	60	75	90
Radius						
1/32	0.0187	0.0374	0.0562	0.0749	0.0937	0.1124
1/16	0.0269	0.0538	0.0807	0.1076	0.1345	0.1614
3/32	0.0351	0.0702	0.1053	0.1404	0.1755	0.2106
1/8	0.0433	0.0866	0.1299	0.1732	0.2165	0.2598
3/16	0.0596	0.1192	0.1788	0.2384	0.2980	0.3576

Thickness	18 B.W.G. 3/64		Aver. T = 0.0479			
Degrees	15	30	45	60	75	90
Radius						
1/32	0.0132	0.0264	0.0396	0.0528	0.066	0.0792
1/16	0.0214	0.0428	0.0642	0.0856	0.107	0.1284
3/32	0.0295	0.059	0.0885	0.118	0.1475	0.177
1/8	0.0377	0.0754	0.1131	0.1508	0.1885	0.2262
3/16	0.0541	0.1082	0.1623	0.2164	0.2705	0.3246

TABLE I.—BENDING ALLOWANCE FOR SHEET METAL—(*Continued*)

Thickness	1/8		T = 0.125			
Degrees	15	30	45	60	75	90
Radius						
1/32	0.0213	0.0425	0.0637	0.085	0.1063	0.1275
1/16	0.0294	0.0589	0.0883	0.1178	0.1472	0.1767
3/32	0.0376	0.0752	0.1128	0.1504	0.188	0.2256
1/8	0.0458	0.0916	0.1374	0.1832	0.229	0.2748
3/16	0.0621	0.1243	0.1864	0.2486	0.3107	0.3729

Thickness	16 B.W.G.		1/64 Aver. T = 0.0637			
Degrees	15	30	45	60	75	90
Radius						
1/32	0.0149	0.0299	0.0449	0.0599	0.0749	0.0899
1/16	0.0231	0.0463	0.0694	0.0926	0.1157	0.1389
3/32	0.0313	0.0627	0.0941	0.1255	0.1569	0.1882
1/8	0.0395	0.079	0.1185	0.158	0.1975	0.237
3/16	0.0559	0.1118	0.1676	0.2236	0.2795	0.3353

Thickness	3/16		T = 0.1875			
Degrees	15	30	45	60	75	90
Radius						
1/32	0.0278	0.0556	0.0834	0.1112	0.139	0.1668
1/16	0.036	0.072	0.108	0.144	0.180	0.216
3/32	0.0441	0.0883	0.1324	0.1766	0.2208	0.2649
1/8	0.0523	0.1047	0.1570	0.2094	0.2617	0.3141
3/16	0.0687	0.1374	0.2061	0.2748	0.3435	0.4122

for the struts, as is common practice. The engine mounting is of laminated wood, with two strips of spruce in the center and a strip of ash top and bottom. Special mountings are provided for the tail skids which allow great latitude of movement with a minimum of breakage.

Wing frames are standardized, each piece being made to drawing and the pieces made up for stock. These are then taken from the stockroom in sufficient quantity to build one or more wings, which are loaded on a truck and wheeled to the wing assembly department. Here the frames are assembled and carefully finished, and the wing, or panel, is then ready for covering. The covers are made up to pattern, slipped over the wing frame and sewed in place. No tacking is used except as a temporary fastening while the cover is being sewed on the frame. It is then ready for the coat of "dope," which shrinks the cloth taut on the frames and also makes it waterproof.

Ailerons, rudders, elevating planes and stabilizing planes all go through the same process, except that some of these have frames made entirely of metal, while others are made of combinations of wood and metal. The method of covering is the same in both cases, however, except that no temporary tacking is possible on the all-metal frames. Then the wings and other parts are ready for assembling into their respective units and for final assembly on the completed machine.

The wings are tied together with guy wires of substantial size, these being of wire cable with thimbles spliced into the ends for fastening into the various fittings and to the turnbuckles, by which they are kept taut. The splicing of these wire cables around the thimbles revives an art which formerly belonged to the seafaring man. It results in a most substantial fastening, and safety is the chief requirement in an airplane. This splicing is now done very deftly and rapidly by women as well as by men, which is hardly in keeping with nautical lore.

The prime essential in airplane building is careful work at every turn, and this is impressed on the workers by frequent signs which read, "A Hidden Defect May Cause the Death of a Man." All material is carefully tested, steels are broken to test strength and toughness, wood is tested both in the solid and when glued up, and the greatest care possible is taken to avoid error.

Wood to be glued is heated in special ovens before the glue is applied, so that the latter may keep hot and liquid until the

Table II.—Drill Sizes

Taper Pins

Pin size	Diameter end of reamer	Fractional size	Drill size	Decimal size	Fractional size
00000	0.078	5/64	No. 46	0.081	5/64
0000	0.091	3/32	No. 42	0.0935	3/32
000	0.108	7/64	No. 34	0.1110	7/64
00	0.125	1/8	No. 30	0.1285	1/8
0	0.134	9/64	No. 28	0.1405	9/64
1	0.145	9/64	No. 25	0.1495	5/32
2	0.161	5/32	No. 19	0.166	11/64
3	0.182	3/16	No. 13	0.185	3/16
4	0.205	13/64	No. 3	0.213	7/32
5	0.239	15/64	D or 1/4	0.246	1/4
6	0.270	17/64		0.250	
7	0.328	21/64	J	0.277	9/32
8	0.395	25/64	Q	0.332	21/64
9	0.479	31/64	Y or 13/32	0.404	13/32
10	0.578	37/64		0.406	
			31/64	0.484	31/64
			19/32	0.59375	19/32

Cotter and Clevis Pins

Pin size	Decimal size	Fractional size	Drill size	Decimal size	Fractional size
1/16	0.0625	1/16	No. 52	0.0635	1/16
3/32	0.09375	3/32	No. 41	0.096	3/32
1/8	0.125	1/8	No. 30	0.1285	1/8
5/32	0.15625	5/32	No. 21	0.1590	5/32
3/16	0.1875	3/16	No. 12	0.189	3/16
7/32	0.21875	7/32	No. 2	0.221	7/32
1/4	0.250	1/4	F or 1/4	0.257	1/4
9/32	0.28125	9/32		0.250	
5/16	0.3125	5/16	L or 9/32	0.290	9/32
3/8	0.375	3/8		0.281	
	0.4375	7/16	O or 5/16	0.316	5/16
	0.5	1/2		0.3125	
			V or 3/8	0.377	3/8
				0.375	
			7/16	0.4375	7/16
			1/2	0.5	1/2

parts can be properly clamped in the gluing press. The glue itself is kept at a uniform temperature and is made up fresh each day so as to secure the best possible results and to avoid the danger of laminations or glued joints becoming loose through inferior glue or improper working conditions.

Table III.—Drill Sizes for Wood Screws, Machine Screws and Bolts

Screw or bolt size	Decimal size	Fractional size	Drill size	Decimal size	Fractional size
No. 0	0.060	1/16	No. 52	0.0635	1/16
No. 1	0.073	5/64	No. 48	0.076	5/64
No. 2	0.086	3/32	No. 43	0.089	3/32
No. 3	0.099	3/32	No. 35	0.1100	7/64
No. 4	0.112	7/64	No. 32	0.116	7/64
No. 5	0.125	1/8	No. 30	0.1285	1/8
No. 6	0.138	9/64	No. 28	0.1405	9/64
No. 7	0.151	5/32	No. 23	0.154	5/32
No. 8	0.164	11/64	No. 19	0.166	11/64
No. 9	0.177	11/64	No. 15	0.180	3/16
No. 10	0.190	3/16	No. 10	0.1935	3/16
1/4	0.250	1/4	F or 1/4	0.257 0.250	1/4
5/16	0.3125	5/16	O or 5/16	0.316 0.3125	5/16
3/8	0.375	3/8	V or 3/8	0.377 0.375	3/8
7/16	0.4375	7/16	7/16	0.4375	7/16
1/2	0.5	1/2	1/2	0.5	1/2

Another example of the care taken is shown in the preceding tables of allowable bends for sheet steel. The data were carefully worked out from actual tests so as to avoid fractures when bends are necessary as they are in many cases. The other tables are also useful in aircraft work.

Inches to Decimals and Millimeters

Inches	Decimals	Millimeters	Inches	Decimals	Millimeters
1/64	0.015625	0.3968	33/64	0.515625	13.0966
1/32	0.03125	0.7937	17/32	0.53125	13.4934
3/64	0.046875	1.1906	35/64	0.546875	13.8903
1/16	0.0625	1.5874	9/16	0.5625	14.2872
5/64	0.078125	1.9843	37/64	0.578125	14.6841
3/32	0.09375	2.3812	19/32	0.59375	15.0809
7/64	0.109375	2.7780	39/64	0.609375	15.4778
1/8	0.125	3.1749	5/8	0.625	15.8747
9/64	0.140625	3.5718	41/64	0.640625	16.2715
5/32	0.15625	3.9686	21/32	0.65625	16.6684
11/64	0.171875	4.3655	43/64	0.671875	17.0653
3/16	0.1875	4.7624	11/16	0.6875	17.4621
13/64	0.203125	5.1592	45/64	0.703125	17.8590
7/32	0.21875	5.5561	23/32	0.71875	18.2559
15/64	0.234375	5.9530	47/64	0.734375	18.6527
1/4	0.25	6.3498	3/4	0.75	19.0496
17/64	0.265625	6.7467	49/64	0.765625	19.4465
9/32	0.28125	7.1436	25/32	0.78125	19.8433
19/64	0.296875	7.5404	51/64	0.796875	20.2402
5/16	0.3125	7.9373	13/16	0.8125	20.6371
21/64	0.328125	8.3342	53/64	0.828125	21.0339
11/32	0.34375	8.7310	27/32	0.84375	21.4308
23/64	0.359375	9.1279	55/64	0.859375	21.8277
3/8	0.375	9.5248	7/8	0.875	22.2245
25/64	0.390625	9.9216	57/64	0.890625	22.6214
13/32	0.40625	10.3185	29/32	0.90625	23.0183
27/64	0.421875	10.7154	59/64	0.921875	23.4151
7/16	0.4375	11.1122	15/16	0.9375	23.8120
29/64	0.453125	11.5091	61/64	0.953125	24.2089
15/32	0.46875	11.9060	31/32	0.96875	24.6057
31/64	0.484375	12.3029	63/64	0.984375	25.0026
1/2	0.5	12.6997	1	1	25.3995

Degrees Fahrenheit to Degrees Centigrade

°F.	0	1	2	3	4	5	6	7	8	9
0	—17.8	—17.2	—16.7	—16.1	—15.6	—15.0	—14.4	—13.9	—13.3	—12.8
10	—12.2	—11.7	—11.1	—10.6	—10.0	— 9.4	— 8.9	— 8.3	— 7.8	— 7.2
20	— 6.7	— 6.1	— 5.6	— 5.0	— 4.4	— 3.9	— 3.3	— 2.8	— 2.2	— 1.7
30	— 1.1	— 0.6	0.0	0.6	1.1	1.7	2.2	2.8	3.3	3.9
40	4.4	5.0	5.6	6.1	6.7	7.2	7.8	8.3	8.9	9.4
50	10.0	10.6	11.1	11.7	12.2	12.8	13.3	13.9	14.4	15.0
60	15.6	16.1	16.7	17.2	17.8	18.3	18.9	19.4	20.0	20.6
70	21.1	21.7	22.2	22.8	23.3	23.9	24.4	25.0	25.6	26.1
80	26.7	27.2	27.8	28.3	28.9	29.4	30.0	30.6	31.1	31.7
90	32.2	32.8	33.9	33.9	34.4	35.0	35.6	36.1	36.7	37.2
100	37.8	38.3	38.9	39.4	40.0	40.6	41.1	41.7	42.2	42.8
110	43.3	43.9	44.4	45.0	45.6	46.1	46.7	47.2	47.8	48.3
120	48.9	49.4	50.0	50.6	51.1	51.7	52.2	52.8	53.3	53.9
130	54.4	55.0	55.6	56.1	56.7	57.2	57.8	58.3	58.9	59.4
140	60.0	60.6	61.1	61.7	62.2	62.8	63.3	63.9	64.4	65.0
150	65.6	66.1	66.7	67.2	67.8	68.3	68.9	69.4	70.0	70.6
160	71.1	71.7	72.2	72.8	73.3	73.9	74.4	75.0	75.6	76.1
170	76.7	77.2	77.8	78.3	78.9	79.4	80.0	80.6	81.1	81.7
180	82.2	82.8	83.3	83.9	84.4	85.0	85.6	86.1	86.7	87.2
190	87.8	88.3	88.9	89.4	90.0	90.6	91.1	91.7	92.2	92.8
200	93.3	93.9	94.4	95.0	95.6	96.1	96.7	97.2	97.8	98.3
210	98.9	99.4	100.0	100.6	101.1	101.7	102.2	102.8	103.3	103.9
220	104.4	105.0	105.6	106.1	106.7	107.2	107.8	108.3	108.9	109.4
230	110.0	110.6	111.1	111.7	112.2	112.8	113.3	113.9	114.4	115.0
240	115.6	116.1	116.7	117.2	117.8	118.3	118.9	119.4	120.0	120.6
250	121.1	121.7	122.2	122.8	123.3	123.9	124.4	125.0	125.0	126.1
260	126.7	127.2	127.8	128.3	128.9	129.4	130.0	130.6	131.1	131.7
270	132.2	132.8	133.3	133.9	134.4	135.0	135.6	136.1	136.7	137.2
280	137.8	138.3	138.9	139.4	140.0	140.6	141.1	141.7	142.2	142.8
290	143.3	143.9	144.4	145.0	145.6	146.1	146.7	147.2	147.8	148.3
300	148.9	149.4	150.0	150.6	151.1	151.7	152.2	152.8	153.3	153.9

To change temperature from Fahrenheit to centigrade proceed as follows: Substract 32 from Fahrenheit temperature. Multiply by 5 and divide by 9.

Conversion Table of Cubic Measures

Metric					English			
Cubic kilometers	Cubic meter	Cubic decimeter	Cubic centimeter	Cubic millimeter	Cubic inches	Cubic feet	Cubic yard	Cubic mile
1	10^9	10^{12}	10^{15}	10^{18}	$61,024\times10^9$	$35,314\times10^6$	$1,308\times10^6$	0.240
10^{-9}	1	10^3	10^6	10^9	61,024	35.314	1,308	
10^{-12}	10^{-3}	1	10^3	10^6	61.024	0.0353	0.001308	
10^{-15}	10^{-6}	10^{-3}	1	10^3	0.061	0.0000353	0.000001308	
10^{-18}	10^{-9}	10^{-6}	10^{-3}	1	0.000061	353×10^{-10}	0.0013×10^{-6}	
163×10^{-16}	163×10^{-7}	0.0163	16.387	16,387	1	0.00057	0.0000213	
$2,832\times10^{-14}$	0.02832	28.32	2,831.7	28,320,000	1,728	1	0.037	
765×10^{-12}	0.7646	764.6	765,000	765,000,000	46,656	27	1	
4.164	$4,164\times10^6$	$4,164\times10^9$	$4,164\times10^{12}$	$402,688\times10^{15}$	$46,656\times1,760^3$	$27\times1,760^3$	$1,760^3$	1

Conversion Table Volumes

Metric			English							
Cubic centimeter	Cubic decimeter (liter)	Cubic meter	Cubic inch	Pint, liquid	Pint, dry	Quart, liquid	Quart, dry	Gallon	Cubic feet	Cubic yard
1	0.001	0.000001	0.0610	0.00211	0.00181	0.00105	0.000908	0.000264	0.000035	0.000001308
1,000	1	0.001	61.025	2.1133	1.8162	1.056	0.908	0.2642	0.03531	0.001308
1,000,000	1,000	1	6,102.3	2,113.3	1,816.2	1,056.65	908	264.2	35.31	1.308
16.39	0.0164	164×10^{-7}	1	0.0346	0.0298	0.0173	0.0148	0.0036	0.000579	215×10^{-7}
473.18	0.4731	0.00047	28.87	1	0.86	0.5	0.43	0.125	0.0167	0.00062
550.6	0.5506	0.0005	33.60	1.163	1	0.582	0.5	0.0141	0.0194	0.00072
946.36	0.9644	0.00094	57.75	2	1.721	1	0.86	0.25	0.0334	0.00124
1,101	1.101	0.001101	67.20	2.326	2	1.164	1	0.2827	0.0389	0.00144
3,785	3.785	0.0037	231	8	68.85	4	0.344	1	0.1337	0.00495
28,317	28.317	0.0283	1,728	59.84	51.43	29.92	25.71	7.48	1	0.03705
764,600	764.6	0.764	46,656	1,615.68	1,388.61	807.84	694.3	201.96	27	1

SECTION XXVI

TERMS USED IN AËRONAUTICS

The following list of aëronautical terms, adopted by the National Advisory Committee for Aëronautics, has been prepared with a view to eliminating the duplication, confusion and erroneous use of terms.

Acceleration.—Increase in velocity.

Aerodynamics.—The science of air in motion

Aërodrome.—The European name for a flying field. Formerly meant any flying machine.

Aërofoil.—A thin wing-like rigid structure, flat or curved, designed to obtain reaction upon its surfaces from the air through which it moves.

Aëronautics.—The science of aerial navigation.

Aeronaut.—The pilot of a balloon.

Aëroplane.—See Airplane.

Aileron.—A movable auxiliary surface used for the control of rolling motion—that is, rotation about the fore-and-aft axis.

Aircraft.—Any form of craft designed for the navigation of air—airplanes, balloons, dirigibles, helicopters, kites, kite balloons, ornithopters, gliders, etc.

Airplane.—A form of aircraft heavier than air, which has wing surfaces for air support, with stabilizing surfaces, rudders for steering, and power plant for propulsion through the air. This term is commonly used in a more restricted sense to refer to airplanes fitted with landing gear suited to operation from the land. If the landing gear is suited to operation from the water, the term "seaplane" is used. (See definition.)

Pusher.—A type of airplane with the propeller or propellers in rear of the wings.

Tractor.—A type of airplane with the propeller or propellers in front of the wings.

Air Pocket.—A local movement or condition of the air which may affect control of the airplane.

Air-screw.—See Propeller.

Air-speed Indicator.—An instrument for measuring the velocity of the air, with respect to the object to which the instrument is fixed.

Air-speed Meter.—An instrument designed to measure the velocity of an aircraft with reference to the air through which it is moving.

Altimeter.—An instrument mounted on an aircraft to continuously indicate its height above the surface of the earth.

Anemometer.—An instrument for measuring the velocity of the wind or air currents with reference to the earth or some fixed body.

Angle.—

Of Attack.—The angle between the direction of the relative wind and the chord of an aërofoil, or the fore-and-aft axis of a body.

Critical.—The angle of attack at which the lift is a maximum.

Dihedral.—See Dihedral.

Gliding.—The angle the flight path makes with the horizontal when flying in still air under the influence of gravity alone.

Incidence.—The angle of the planes with center line of the airplane. For the rigger this means the angle the chord of the wing makes with the axis of the propeller.

Aspect Ratio.—The ratio of spread to chord of an aërofoil.

Aviation.—Same as Aëronautics.

Aviator.—The operator or pilot of heavier-than-air craft. This term may be applied equally, regardless of the sex of the operator.

Axes of an Aircraft.—Three fixed lines of reference; usually centroidal and mutually rectangular. The principal longitudinal axis in the plane of symmetry, usually parallel to the axis of the propeller, is called the fore-and-aft axis (or longitudinal axis); the axis perpendicular to this in the plane of symmetry is called the vertical axis; and the third axis, perpendicular to the other two, is called the athwartship axis (or transverse or lateral axis). In mathematical discussions the first of these axes is called the X-axis, the second the Z-axis, and the third the Y-axis.

Ballonet.—A small balloon within the interior of a balloon or dirigible for the purpose of controlling the ascent or descent, and for maintaining pressure on the outer envelope to prevent deformation. The ballonet is kept inflated with air at the required pressure, under the control of a blower and valves.

Balloon.—A form of aircraft comprising a gas bag and a car, whose sustentation depends on the buoyancy of the contained gas, which is lighter than air.

Captive.—A balloon restrained from free flight by means of a cable attaching it to the earth.

Kite.—An elongated form of captive balloon, fitted with tail appendages to keep it headed into the wind, and deriving increased lift due to its axis being inclined to the wind.

Bank.—To incline an airplane laterally—that is, to rotate it about the fore-and-aft axis. Right bank is to incline the airplane with the right wing down.

Banking Rudder.—See Aileron.

Barograph.—An instrument used to record variations in barometric pressure. In aëronautics the charts on which the records are made are prepared to indicate altitudes directly instead of barometric pressure.

Barometer.—An instrument for indicating the density of the air.

Bay.—The space enclosed by two struts and whatever they are fixed to. (English.)

Biplane.—A form of airplane in which the main supporting surface is divided into two parts, one above the other.

Body of an Airplane.—A structure, usually inclosed, which contains in a stream-line housing the power plant, fuel, passengers, etc.

Boom.—The long spars joining the tail of a pusher airplane to its main lifting surface.

Bracing.—A system of struts and tie wires to transfer a force from one point to another.

Cabane.—A combination of two posts or horns over the fuselage from which the anti-lift wires are suspended.

Cabré.—A flying attitude in which the angle of attack is greater than normal; tail down; down by the stern—tail low.

Camber.—The convexity or rise of a curve of an aërofoil from its chord, usually expressed as the ratio of the maximum departure of the curve from the chord as a fraction thereof. "Top camber" refers to the top surface of an aërofoil, and "bottom camber" to the bottom surface; "mean camber" is the mean of these two.

Canard.—The name (literally meaning "duck") given to a type of airplane of which the longitudinal stabilizing surface is in front of the main lifting surface.

Capacity.—

Lifting.—The maximum flying load of an aircraft.

Carrying.—Excess of the lifting capacity over the dead-load of an aircraft, which latter includes structure, power plant and essential accessories.

Carrying Capacity.—See Capacity.

Castle-nut.—A nut slotted to receive a cotter pin or other retaining device.

Cavitation of Propeller.—The tendency to produce a cavity in the air.

Cell.—The upper and lower surfaces which are held together by struts, wires, etc., to form a "cell" or box.

Center.—The point in which a set of effects is assumed to be accumulated producing the same effect as if all were concentrated at this point.

Of Buoyancy.—The center of gravity of the fluid displaced by the floating body.

Of Pressure of an Aërofoil.—The point on the chord of an element of an aërofoil, prolonged if necessary, through which the line of action of the resultant air force passes.

Of Pressure of a Body.—The point on the axis of a body, prolonged if necessary, through which the line of action of the resultant air force passes.

Centrifugal Force.—The force tending to force outward any body moving in a curved path.

Chassis.—The wheels, axles, shock absorbers, skids and struts connecting them to the rest of the machine.

Chord.—

Of an Aërofoil Section.—A right line tangent to the under curve of the aërofoil section at the front and rear.

Length.—The length of the chord is the length of the aërofoil section projected on the chord, extended if necessary.

Clevis.—A "U" shaped fitting used to join a wire to another fitting.

Cloche.—The bell-shaped frame which forms the lower part of pilot's control lever in Bleriot airplane (literally meaning "bell").

Cockpit.—The openings and space in the fuselage where pilot or observer sits.

Control Lever.—The lever or stick for controlling air surfaces. Often called "joy-stick."

Controls.—A general term applying to the means provided for operating the devices used to control speed, direction of flight, and attitude of an aircraft.

Cotter Pin.—A pin of half-round steel doubled back upon itself After being placed in its hole, the ends may be spread locking it in place.

Critical Angle.—See Angle, Critical.

Décalage.—An increase in the angular setting of the chord of an upper wing of a biplane with reference to the chord of the lower wing.

Developed Area of a Propeller.—A layout of the area of a propeller blade designed to represent the total area of the driving face, in which the elements of area are developed as if unfolded onto the plane of the drawing (necessarily an approximation on definite assumptions, as no true development of the helix can be made).

Dihedral Angle.—The angle which the wings make with a horizontal line from tip to tip of wing. The dihedral angle of the upper wing may and frequently does differ from that of the lower wing in a biplane.

Dirigible.—A form of balloon, the outer envelope of which is of enlongated form, provided with a propelling system, car, rudders and stabilizing surfaces.

Non-rigid.—A dirigible whose form is maintained by the pressure of the contained gas assisted by the car-suspension system.

Rigid.—A dirigible whose form is maintained by a rigid structure contained within the envelope.

Semi-rigid.—A dirigible whose form is maintained by means of its attachment to an exterior girder construction containing the car.

Disc Area of a Propeller.—The total area of the disc swept by the propeller tips.

Dive.—To descend so steeply as to produce more than flying speed.

Diving Rudder.—See Elevator.

Dope.—A general term applied to the materials used in treating the cloth surface of airplane members to increase strength, produce tautness and act as a filler to maintain air-tightness; usually of the cellulose type.

Drag.—The total resistance to motion through the air of an aircraft—that is, the sum of the drift and head resistance.

Drift.—The component of the resultant wind pressure and an aërofoil or wing surface parallel to the air stream attacking the surface.

Active.—Drift or resistance produced by lifting surfaces.

Passive.—Drift produced by detrimental or non-lifting surfaces.

Edge. *Entering.*—The front edge of a wing or any aërofoil.

Trailing.—The rear edge of a wing or any aërofoil.

Efficiency.—The work delivered divided by the work put into a machine, or output divided by input.

Airplane.—Lift and velocity divided by resistance.

Engine.—Brake horsepower divided by indicated horsepower.

Propeller.—Thrust in foot pounds divided by horsepower of engine × 33,000.

Elevator.—A hinged surface for controlling the longitudinal attitude of an aircraft—that is, its rotation about the athwartship axis.

Empennage.—Tail planes.

Engine, Right or Left Hand.—The distinction between a right-hand and a left-hand engine depends on the rotation of the output shaft, whether this shaft rotates in the same direction as the crank or not. A right-hand engine is one in which, when viewed from the output shaft, looking toward the output end, the shaft is seen to rotate clockwise.

Engine, Anti-normal.—An engine, when viewed from the propeller end, whose propeller rotates in a clock-wise direction.

Engine, Normal.—An engine, when viewed from the propeller end the propeller is seen to rotate in an anti-clockwise direction.

Entering Edge.—See Edge.

Eye-bolt.—A bolt having an eye in its head to which a wire may be attached.

Factor of Safety.—The breaking strength of a piece divided by the maximum stress it is called upon to bear.

Fairing.—A covering of thin wood or sheet aluminum bent over detrimental shapes to give a "fair" or stream-line shape as in the entering edge of wings, or rear of stall landing struts.

Fairlead.—A piece of tubing through which control wires are passed in order that they may be properly directed.

Ferrule.—A wrapping of tin or some similar material around the butt end of any member or a splice.

Fineness.—The proportion of length to maximum width.

Fins.—Small planes on aircraft to promote stability; for example, vertical tail fins, horizontal tail fins, skid fins, etc.

Flight Path.—The path of the center of gravity of an aircraft with reference to the air.

Float.—That portion of the landing gear of an aircraft which provides buoyancy when it is resting on the surface of the water. See Position.

Flying Boat.—An aeroplane of such a design that its body acts as a boat on the water and carries the empennage and passengers. It also carries the motor at times, but the general position of the motor in this type of machine is in the main cell.

Foot-pound.—The measure of work; 1 pound raised 1 foot.

Fuselage.—See Body.

Gap.—The distance between the projections on the vertical axis of the entering edges of an upper and lower wing of a biplane.

Girder.—A structure designed to resist bending and to combine strength and lightness.

Glide.—To fly without power.

Glider.—A form of aircraft similar to an airplane, but without any power plant. When utilized in variable wind it makes use of the soaring principles of flight and is sometimes called a "soaring machine."

Gliding Angle.—See Angle, Gliding.

Guy.—A rope, chain, wire or rod attached to an object to guide or steady it, such as guys to wing, tail or landing gear.

Gyroscope.—A heavy wheel revolving at high speed which has a tendency to maintain its plane of rotation against disturbing forces.

Hangar.—A shed for housing airplanes.

Head Resistance.—The total resistance to motion through the air of all parts of an aircraft not a part of the main lifting surface. Sometimes termed "parasite resistance."

Helicopter.—A form of aircraft whose support in the air is derived from the vertical thrust of propellers.

Horizontal Equivalent.—The horizontal projection of a body.

Horn.—A mast usually made of steel tube, to which the control wires on control surfaces are attached.

Horse Power, Thrust.—The product of the pitch of a propeller in feet less the slip, its thrust in lbs., its number of revolutions per minute, and a constant, $1/33000$.

Hydroaeroplane.—Any type of aeroplane designed to rise from and light on the water.

Hydroplane.—A form of pontoon used in hydroaeroplanes that has a planing effect upon the water when given forward motion.

Inclinometer.—An instrument for measuring the angle made by any axis of an aircraft with the horizontal.

Joy-stick.—See Control Lever.

K-strut.—An interplane strut, shaped as the letter "K," taking place of both front and rear struts, of the maincell, as well as drift and antidrift wires.

Keel Plane Area.—The total effective area of an aircraft which acts to prevent skidding or side slipping.

Keel-surface.—All the surface to be seen when viewing an aeroplane from the side.

King-post.—A strut passing through a surface usually attached to the main spar, to which brace wires are attached. Sometimes used as a lever for control surfaces.

Kite.—A form of aircraft without other propelling means than the towline pull, whose support is derived from the force of the wind moving past its surface.

Kite Balloon.—See Balloon, Kite.

Lamination.—A term applied to two or more pieces fastened together by glue or other means to give more strength to the unit thus made up.

Landing Gear.—The understructure of an aircraft designed to carry the load when resting on, or running on, the surface of the land or water.

Lateral Stability.—See Stability, Lateral.

Leading Edge.—See Entering Edge.

Leeway.—The angular deviation from a course over the earth, due to cross-currents of wind.

Lift.—The component of the force due to the air pressure of an aërofoil, resolved perpendicular to the flight path in a vertical plane.

Lift Bracing.—See Stay.

Lift-drift Ratio.—The proportion of lift to drift, or resistance.

Lifting Capacity.—See Capacity, Lifting.

Load, Full.—See Capacity, Lifting.

Reserve (or useful).—See Capacity, Carrying.

Loading.—See Wing Loading.

Longeron.—One of the four or more long spars running lengthwise of the body or fuselage.

Longitudinal.—A fore and aft member of the framing of an airplane body, or of the floats, usually continuous across a number of points of support.

Longitudinal Stability.—See Stability, Longitudinal.

Louvre:—An opening usually in an engine hood to allow passage of air for ventilation.

Metacenter.—The point of intersection of a vertical line through the center of gravity of the fluid displaced by a floating body when it is tipped through a small angle from its position of equilibrium and the inclined line which was vertical through the center of gravity of the body when in equilibrium. There is, in general, a different metacenter for each type of displacement of the floating body.

Monoplane.—A form of airplane whose main supporting surface is disposed as a single wing on each side of the body.

Montant.—A strut in the fuselage.

Motor.—See Engine.

Multiplane.—An airplane with three or more wing surfaces.

Nacelle.—See Body. Usually refers to nose of body.

Natural Stability.—See Stability.

Neutral Lift Line.—A straight line from the trailing edge of an aerofoil, so placed that it is parallel to the direction of motion when there is no lift.

Normal Plane.—Another expression for diametral plane, and merely refers to the maximum cross sectional projection of the body. It also refers to a flat surface held perpendicular to the air current.

Nose Dive.—A dangerously steep descent, head-on.

Ornithopter.—A form of aircraft deriving its support and propelling force from flapping wings.

Outrigger.—A spar running from the main cell to the longitudinal or directional control surfaces. Does not apply to fuselage spars.

Pancake.—To stall and drop, or settle to the ground in landing.

Pitch of Propeller.—The distance a propeller would advance in one revolution if the air were solid.

Pitot Tube.—A tube with an end open square to the fluid stream, used as a detector of an impact pressure. More usually associated with a concentric tube surrounding it having perforations normal to the axis for indicating static pressure. The velocity of the fluid can be determined from the difference between the impact pressure and the static pressure. This instrument is often used to determine the velocity of aircraft through the air.

Plane.—Sometimes applied to the whole flying machine, but more often to a wing.

Pontoon.—A float used under fuselage and wings to support plane when landing on or starting from the water.

Power, Margin of.—Power available above that necessary to maintain horizontal flight.

Propeller.—

Propeller Torque.—The force giving a machine a tendency to rotate in a direction opposite to that in which the propeller is turning due to the action of the propeller on the air.

Developed Area of.—See Developed Area of a Propeller.

Disc Area of.—See Disc Area of a Propeller.

Right-hand.—One in which the helix is right-handed.

Pusher.—See Airplane.

Pylon.—A marker of a course.

Race of a Propeller.—The air stream delivered by the propeller.

Remon.—A local movement or condition of the air which may cause displacement of an airplane.

Rib.—See Wing.

Right (or Left) Hand—

Engine.—See Engine.

Propeller.—See Propeller, Right-hand.

Rigid Dirigible.—See Dirigible, Rigid.

Rudder.—A hinged or pivoted surface, usually more or less flat or stream-lined, used for the purpose of controlling the attitude of an aircraft about its vertical axis when in motion.

Rudder Bar.—Control lever moved by pilot's feet and operating the rudder.

Saddle.—A small piece of tin curved in the shape of a wire loop and soldered into the loop so that the wire cable will not fray by rubbing on the fitting.

Seaplane.—A particular form of airplane in which the landing gear consists of pontoons or other devices suited to operation from the water.

Serving.—To bind with cord or wire; used in connection with joints and splices.

Shackle.—See "Clevis."

Shock Absorber.—An elastic member connecting the landing wheels or skid to a fixed member of the machine.

Side Slipping.—Sliding toward the center of a turn. It is due to excessive amount of bank for the turn being made, and is the opposite of skidding.

Skidding.—Sliding sidewise in flight away from the center of the turn. It is usually caused by insufficient banking in a turn, and is the opposite of side slipping.

Skids.—Long wooden or metal runners designed to prevent nosing of a land machine when landing or to prevent drop into holes or ditches in rough ground. Generally designed to function should the wheels collapse or fail to act.

Skin Friction.—Friction between air and surface of the planes.

Slip.—This term applies to propeller action and is the difference between the actual velocity of advance of an aircraft and the speed calculated from the known pitch of the propeller and its number of revolutions.

Soaring Machine.—See Glider.

Socket.—A type of fitting taking the but end of a spar or strut and surrounding it completely.

Span.—Distance from tip to tip of wings.

Spar.—Any long piece of wood or other material.

Main.—The spar to which all the ribs are attached. It also transfers a good share of the lift from the ribs to the bracing.

Splice, American.—A form of solid wire splice in which a loop is made and the returning end is attached to the main wire by a tin ferrule. The whole job is soldered.

Splice, to.—To join two or more parts together.

Splice, Eye.—A form of cable splice in which a loop is made and the returning end is woven into the main wire. The job is served with twine but not soldered.

Splice, French.—A type of solid wire splice in which a loop is made and the returning end is attached to the main wire by a ferrule made from about seven turns of the same size wire being spliced. No solder is used.

Splice, Running.—A form of cable splice in which a loop is made and the returning end is attached to the main wire by a serving of a fine wire. The whole job is soldered.

Spread.—The maximum distance laterally from tip to tip of an airplane wing.

Spreader.—A horizontal compression member in a fuselage running in a lateral direction.

Stability.—The quality of an aircraft in flight which causes it to return to a condition of equilibrium when meeting a disturbance. (This is sometimes called "dynamical stability.")

Directional.—Stability with reference to the vertical axis.

Inherent.—Stability of an aircraft due to the disposition and arrangement of its fixed parts.

Lateral.—Stability with reference to the longitudinal (or fore and aft) axis.

Longitudinal.—Stability with reference to the lateral (or athwartship) axis.

Stabilizer.—See Fins.

Mechanical.—Any automatic device, gyroscopic or otherwise, designed to secure stability in flight.

Stagger.—The amount of advance of the entering edge of the upper wing of a biplane over that of the lower; it is considered positive when the upper surface is forward.

Stalling.—A term describing the condition of an airplane which from any cause has lost relative speed necessary for steerageway and control.

Statoscope.—An instrument to detect the existence of a small rate of ascent or descent, principally used in ballooning.

Stay.—A wire, rope, or the like, used as a tie-piece to hold parts together or to contribute stiffness; for example, the stays of the wing and body trussing.

Step.—A break in the form of the bottom of a float.

Strain.—Deformation or rupture caused by stress.

Stream-line Flow.—A term in hydromechanics to describe the condition of continuous flow of a fluid, as distinguished from eddying flow where discontinuity takes place.

Stream-line Shape.—A shape intended to avoid eddying or discontinuity and to preserve stream-like flow, thus keeping resistance to progress at a minimum.

Stress.—The load imposed on any piece or structure.

Strut.—A compression member of a truss frame; for instance, the vertical members of the wing truss of a biplane between longerons in a fuselage, etc.

Sweep Back.—The horizontal angle between the lateral (athwartship) axis of an airplane and the entering edge of the main planes.

Tachometer.—An instrument recording the motor speed in revolutions per minute.

Tail.—The rear portion of an aircraft, to which are usually attached rudders, elevators and fins.

Tail Fins or Planes.—The vertical and horizontal surfaces attached to the tail, used for stabilizing.

Tail Slide.—When an airplane slides, or dives, backward.

Thrust Deduction.—Due to the influence of the propellers, there is a reduction of pressure under the stern of the vessel which appreciably reduces the total propulsive effect of the propeller. This reduction is termed "thrust deduction."

Tractor.—See Airplane.

Trailing Edge.—The rearmost portion of an aërofoil.

Triplane.—A form of airplane whose main supporting surfaces are divided into three parts, one above the other.

Truss.—The framing by which the wing loads are transmitted to the body, comprises struts, stays and spars.

Turnbuckle.—A form of wire-tightener consisting of a barrel with an eyebolt screwed in each end.

U-bolt.—A bolt threaded on both ends and shaped as the letter "U." Used in some types to anchor both the wires and fittings. In other cases it is used where hole boring is prohibiitve.

U-bridge.—An arched support passing over the operator's legs and carrying the aileron control wheel. The forward and backward movement of the bridge controls the elevators.

Velometer.—See Air-speed Meter and Anemometer.

Vent.—A tube between the step of a hydroplane and its top to eliminate suction while in a planing attitude.

Vetting.—The process of sighting by eye along edges of spars, planes, etc., to ascertain their alignment.

Vol-piqué.—See Nose Dive.

Vol-plane.—See Glide.

Wake Gain.—Due to the influence of skin friction, eddying, etc., a vessel in moving forward produces a certain forward movement of the fluid surrounding it. The effect of this is to reduce the effective resistance of the hull, and this effect, due to the forward movement of the wake, is termed the "wake gain." In addition to this effect the forward movement of this body of fluid reduces the actual advance of the propeller through the surrounding medium, thereby reducing the propeller horsepower.

Warp.—To change the form of the wing by twisting it, usually by changing the inclination of the rear spar relative to the front spar.

Wash.—Disturbance of the air produced by flight of airplane.

Wash-in.—Increasing angle of incidence toward wing tip.

Wash-out.—Decreasing angle of incidence toward wing tips.

Wind Screen.—A small screen, usually of celluloid, to protect aviator or observer, from air pressure.

Wind Tunnel.—A large tube used for experimenting with surfaces and models, and through which a current of air is forced by a power driven fan. This shows the action of surfaces in flight and gives much useful information.

Wings.—The main supporting surfaces of an airplane.

Wing Loading.—The weight carried per unit area of supporting surface.

Wing Rib.—A fore-and-aft member of the wing structure used to support the covering and to give the wing section its form.

Wing Spar.—An athwartship member of the wing structure resisting tension and compression.

Wire Control.—Wire connecting a controlling surface with the pilot's control lever, wheel or rudder bow.

Drift.—Wire to prevent wings being forced backward during flight.

Landing.—Wire opposed to above, to sustain surface when at rest.

Lift or Flying.—Wire used to brace wings from collapsing upward during flight.

Locking.—Wire (soft) to prevent a turnbuckle or other fitting from losing its adjustment.

Snaking.—Wire (soft) wound spirally or tied around another wire and attached at each end to the framework. Used to prevent the wire around which it is "snaked" from being entangled in propeller in case of breakage.

Yaw.—To swing off the course about the vertical axis, owing to gusts or lack of directional stability.

Angle of.—The temporary angular deviation of the fore-and-aft axis from the course.

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